TEXT FLY WITHIN
THE BOOK ONLY

OF THE

Imperial Agricultural Research Institute, New Delhi

For the year ending 30th June, 1937

with

A BRIEF SURVEY OF THREE DECADES OF RESEARCH AT THE INSTITUTE

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI
1937

List of Agents in India from whom Government of India Publications are available.

(a) Provincial Government Book Depots.

MADRAS:—Superintendent, Government Press, Mount Road, Madras.

BOMBAY:—Superintendent, Government Printing and Stationery, Queen's Road, Bombay.

SIND:—Manager, Sind Government Book Depot and Record Office, Karachi (Sadar).

UNITED PROVINCES:—Superintendent, Printing and Stationery, U. P., Allahabad.

PUNJAB:—Superintendent, Government Printing, Punjab, Lahore.

CENTRAL PROVINCES:—Superintendent, Government Printing, Central Provinces, Nagpur.

ASSAM:—Superintendent, Assam Secretariat Press, Shillong.

BIHAR:—Superintendent, Government Printing, P. O. Gulzarbagh, Patna.

NORTH-WEST FRONTIER PROVINCE:—Manager, Government Printing and Stationery, Peshawar.

ORISSA:—Press Officer, Secretariat, Cuttack.

(b) Private Book-sellers.

Advani Brothers, P. O. Box 100, Cawnpore.
Aero Stores, Karachi.*
Banthiya & Co., Ltd., Station Road, Ajmer.
Bengal Flying Club, Dum Dum Cantt.*
Bhatia Book Depot, Saddar Bazar, Ranikhet.
Bhawnani & Sons, New Delhi.
Book Company, Calcutta.
Booklover's Resort, Talkad, Trivandrum, South India.
Burma Book Club, Ltd., Rangoon.
Butterworth & Co. (India), Ltd., Calcutta.
Careers, Mohini Road, Lahore.
Chatterjee & Co., 3, Bacharam Chatterjee Lane, Calcutta.
Chukervertty, Chatterjee & Co., Ltd., 13, College Square, Calcutta.
City Book Club, 98, Phayre Street, Rangoon.
Das Gupta & Co., 54/3, College Street, Calcutta.
Delhi and U. P. Flying Club, Ltd., Delhi.*
English Book Depot, Ferozepore.
English Book Depot, Taj Road, Agra.
English Bookstall, Karachi.
English Book Store, Abbottabad, N.-W. F. P.
Faqir Chand Marwah, Peshawar Cantt.
Fono Book Agency, Simla.
Gautama Brothers & Co., Ltd., Meston Road, Cawnpore.
Higginbothams, Madras.
Hindu Library, 137/F, Balaram De Street, Calcutta.
Hyderabad Book Depot, Chaderghat, Hyderabad (Deccan).
Imperial Book Depot and Press, near Jama Masjid (Machhliwalan), Delhi.
Indian Army Book Depot, Dayalbagh, Agra.
Indian Army Book Depot, Daryaganj, Delhi.
Indian Book Shop, Benares City.
Indian School Supply Depot, Central Avenue South, P. O. Dharamtala, Calcutta.
Insurance Publicity Co., Ltd., Lahore.
International Book Service, Poona 4.
Jacques & Co., Kamptee Road, Nagpur, Messrs. Neston.
Jaina & Bros., Mori Gate, Delhi, and Connaught Place, New Delhi, Messrs. J. M.
Kamala Book Depot, 15, College Square, Calcutta.
Karnataka Publishing House, Bangalore City.
Keale & Co., Karachi.
Keshao Book Stall, Khadibazar, Belgaum.
Kitabistan, 17-A, City Road, Allahabad.
Krishnaswami & Co., Teppakulam P. O., Trichinopoly Fort, Messrs. S.
Lahiri & Co., Calcutta, Messrs. S. K.
Local Self Govt. Institute, Bombay
London Book Co. (India), Arbab Road, Peshawar, Murree, Nowshera, Rawalpindi.
London Book House, 17, Rajpur Road, Dehra Dun.
Malik & Sons, Sialkot City.
Mathur, B. S., Bookseller, Civil Lines, Jodhpur.
Messrs. U. P. Malhotra & Co., Post Box No. 94, Lahore.
Minerva Book Shop, Anarkali Street, Lahore.
Modern Book Depot, Bazar Road, Sialkot Cantt.
Modern Book Depot, Napier Road, Jullundur Cantt.
Mohanlal Dossabhai Shah, Rajkot.
Nandkishore & Bros., Chowk, Benares City.
New Book Co., "Kitab Mahal," 192, Hornby Road, Bombay
Newman & Co., Ltd., Calcutta, Messrs. W.
Oxford Book and Stationery Company, Delhi, Lahore, Simla, Meerut and Calcutta.
Parikh & Co., Baroda, Messrs. B.
Pioneer Book Supply Co., 20, Shib Narayan Das Lane, Calcutta and 219, Cloth Market, Delhi.
Popular Book Depot, Grant Road, Bombay.
Punjab Religious Book Society, Lahore.
Raghunath Prasad & Sons, Patna City.
Rama Krishna & Sons, Booksellers, Anarkali, Lahore.
Ram Krishna Bros., Opposite Bishrambag, Poona City.
Ram Narain Lal, Katra, Allahabad.
Ramesh Book Depot & Stationery Mart, Kashmere Gate, Delhi.
Ray & Sons, 43, K. & L. Edwardes Road, Rawalpindi, Murree and Peshawar, Messrs. J.
Roy Chowdhury & Co., 72, Harrison Road, Calcutta, Messrs. N. M.
Saraswati Book Depot, 25, Lady Hardinge Road, New Delhi.
Sarcar & Sons, 15, College Square, Calcutta, Messrs. M. C.
Sarkar & Co., Ltd., 18, Shama Charan De Street, and 6, Hastings Street, Calcutta, Messrs. P. C.
Sharada Mandir, Ltd., Nai Sarak, Delhi.
Standard Bookstall, Karachi.
Standard Bookstall, Quetta.
Standard Book Depot, Lahore, Dalhousie and Delhi.
Standard Law Book Society, 69, Harrison Road, Calcutta.
Tara & Sons, Razmak (India), Messrs. B. S.
Taraporevala Sons & Co., Bombay, Messrs. D. B.
Thacker & Co., Ltd., Bombay.
Thacker, Spink & Co., Ltd., Calcutta and Simla.
Tripathi & Co., Booksellers, Princes Street, Kalbadev Road, Bombay, Messrs. N. M.
University Book Agency, Kacheri Road, Lahore.
Upper India Publishing House, Ltd., Literature Palace, Ammuddaula Park, Lucknow.
Varadachary & Co., Madras, Messrs. P.
Venkatasubban, A., Law Bookseller, Vellore,
Wheeler & Co., Allahabad, Calcutta and Bombay, Messrs. A. H.
Young Man & Co. (Regd.), Egerton Road, Delhi.

*Agent for publications on Aviation only.

TABLE OF CONTENTS

SCIENTIFIC REPORTS

OF THE

Imperial Agricultural Research Institute, New Delhi

FOR THE YEAR ENDING JUNE 30, 1937

REPORT OF THE DIRECTOR

(B. VISWA NATH)

I. 1936-37

The transfer of the Imperial Agricultural Research Institute from Pusa to Delhi was completed during the year. It was mentioned in the previous reports that the Bihar earthquake in January 1934 damaged the Institute at Pusa beyond repair and that the Government of India decided to rebuild the Institute on a site within the limits of Imperial Delhi. The project made rapid progress. By November 1936, the construction of the buildings and the move of the staff and equipment from Pusa to Delhi were completed.

His Excellency the Viceroy, the Marquess of Linlithgow, opened the Library—the central building of the Institute—on the 7th of November 1936. In his opening speech, His Excellency paid tributes to the memory of the late Sir Fazl-i-Hussain, Member of the Government of India for Education, Health and Lands, and to the memory of the late Dr. F. J. F. Shaw, the Director of the Institute, through whose efforts the transfer became possible. In declaring the new Institute open, His Excellency said :—

"The Institute has in it, I am confident, the power for further service of infinite value to India; alike to the Provinces and to the Indian States. Its tradition and its reputation are those of established distinction. It has been served by many able and distinguished men with a loyal and disinterested devotion throughout the many years of its existence. I am confident that the present staff will amply sustain the past record of

the institution for scientific achievements of the highest standard. In today declaring open its new home I do so with the wish, which all of us share, that, under its new auspices, its future may be even more brilliant and the service it renders to India even more distinguished than ever before."

The Marquess of Linlithgow was pleased to agree to the Library of the Institute being designated as the Linlithgow Library as a mark of his deep and continuous interest in the welfare of the Institute. The Institute feels honoured by this recognition. His Excellency was further pleased to direct that the Laboratory for Soil Science and Agricultural Chemistry be called the Phipps Laboratory, after Mr. Henry Phipps, the American philanthrophist, who made a generous donation towards part of the cost of founding the original Institute at Pusa.

The normal work of the Institute could not be resumed till a few months after the formal opening. The sorting and testing of the equipment brought from Pusa and arranging it in the respective laboratories were completed by the middle of January 1937, and the contractors completed their fittings by the end of March 1937. Early in April all the laboratories resumed their full normal activities which were interrupted by the earthquake three years ago. The dislocation caused by the move was not allowed to interfere with the work of the post-graduate students. The final dismantling of the laboratories at Pusa was done after the students had dispersed for the summer vacation in May 1936, and by the time they rejoined at Delhi in July 1936 a few rooms were made ready for their work. Provision was made for field work on the substations at Pusa and Karnal, where field experimental work will be carried out until the land at Delhi becomes ready.

The soil at the new Institute is typical old alluvium. The climatic and other conditions are suitable for rain-fed or 'dry' cultivation for which Pusa is not suitable. It is also possible to handle a larger number of crops than was possible at Pusa. The performance of crops as judged by the results of the first harvest after occupation is satisfactory (Plate I).

The Institute, as it is now constituted, consists of six main Sections—Agriculture, Botany, Soil Science and Chemistry, Entomology, Plant Pathology and Sugarcane Breeding. The last mentioned Section is located at Coimbatore. The Agricultural Section has a large substation at Karnal—70 miles from Delhi. The Botanical Section has substations at Pusa for general botanical work, at Simla for potato breeding and at Guntur for tobacco experiments. The Sugarcane Section has a substation at Karnal for testing and selection. The substations of the Botanical and

Sugarcane Sections are financed by the Imperial Council of Agricultural Research. The annual reports of the different Sections are to be found elsewhere in this volume.

During the year under report the Institute has had the unique honour that one of its members, Rao Bahadur T. S. Venkataraman, the Sugarcane Expert, was decorated with a C.I.E. and was elected as the General President of the Indian Science Congress held at Hyderabad in January 1937. In his presidential address to the Congress the Rao Bahadur dealt with the problems of rural reconstruction in India.

Rao Bahadur B. Viswa Nath was elected President of the Agricultural Section of the same session of the Science Congress. In his address to the Section he dealt with the progress of scientific research with reference to agricultural practices in India and initiated the discussion on the need for an All-India Soil Survey.

As the year under report closed the last year of the Institute at Pusa and began the new one at Delhi, it will be appropriate to rapidly review the work of the Institute at Pusa and the problems to be dealt with at Delhi.

II. THE INSTITUTE AT PUSA—1905-1936.

1. The Economic value of the work of the Institute

The value of an institution and the significance of its work will be assessed in proportion to its contribution to the attainment of the objects for which the institution is established and the ideals set before it. Three decades ago, the late Lord Curzon—the then Viceroy and Governor-General of India, to whose initiative and efforts the Pusa Institute owed its origin—in laying the foundation-stone of the Imperial Agricultural Research Institute, said :—

> "Should I find Pusa the centre of a great organisation, with ramifications extending to all parts of the Indian Continent, training a series of students, who will devote their acquired knowledge to the practical pursuit of agriculture and able to point to the tangible results of successful scientific experiment both in the quality of seeds and plants, in the destruction of pests and in the improvement of breeds of cattle ? That is the prospect that I should like to look forward to, and if it be at all realised, then we may be assisting at a rather momentous child birth today."

If the noble Lord were happily alive today and revisited the country, he would be pleased to find his wishes so fully materialised. The Pusa Institute being then the first of its kind in the country was, for many years, the chief stimulus for agricultural

research and progress. Successive batches of young men have been trained in the different allied sciences, for work in the provinces. Improved high yielding varieties of crops have been evolved and distributed extensively, with tangible economic results to the cultivator. To mention only two of the many accomplishments, the improved Coimbatore varieties of sugarcane have replaced over seventy per cent of the indigenous canes, and the Pusa wheats occupy over six million acres or twenty per cent of the area under wheat. Substantial results have been achieved in the improvement of the Sahiwal breed of milch cattle, and over 400 pedigree bull-calves and cows have been supplied to different parts of India. At a conservative estimate, the increase in the agricultural income to the cultivator in one year, directly arising from the work of the Institute, exceeds the total amount of money spent on the Institute in thirty years. The phenomenal development of the Indian sugar industry is due in a great measure to the work of the Sugar Section at Coimbatore.

The research work behind these practical achievements is a long list of 750 published contributions by the members of the Institute. These contributions are made available to the public by means of books, monographs, memoirs, bulletins and articles in Indian and foreign journals, besides the published annual reports. In a review of this kind, it is impossible to make personal references to the long list of a succession of workers at the Institute, who have contributed so much to the science and practice of agriculture, but reference must be made to the early pioneers Mr. (now Sir) Albert Howard, the late Mrs. G. L. C. Howard, the late Major J. W. Leather, Dr. E. J. Butler, the late Professor Maxwell Lefroy, Dr. F. J. Warth, Mr.C. M. Hutchinson and the late Dr. C. A. Barber. These scientists did valuable work, and many recent developments have their foundation in the imagination shown and the care exercised in the early days to seek directions in which improvements could be made or new ideas conceived.

2. The Development of the Institute and its work

The work of the Institute may be reviewed under two divisions : post-graduate education and research. The educational work has for its object the training of young men in methods of research and the basis of instruction is the research work in progress. The research work has a strong economic back-ground and is directed to the study of the scientific principles underlying agricultural practices and improvements.

Post-graduate training.—In the early days when the Provinces and States were developing their agricultural colleges and research institutes, successive batches of a total of 133 scientific

workers—exclusive of the direct recruits to the Indian Agricultural Service, who had also their preliminary training at the Institute—were trained for employment in the Provinces. Most of the heads of sections and their assistants in the agricultural colleges and research institutes in the Provinces were, and many still are, those who spent some time at Pusa before commencing their work in their respective Provinces and States. There is hardly any other organisation for agricultural research in existence in the country, which is not a development of the initial steps taken by the Pusa Institute.

The general advance all over the country was soon followed by a demand for the provision of facilities for more advanced study and research. The educational work of the Institute was reorganised, and suitable post-graduate courses were instituted. Since the inception of these courses 104 students have been admitted. Of these, 12 left without completing the course, 67 passed out and 25 are still under training. Of the 67 who have passed out, 55 are definitely known to have been employed either in the departments of agriculture or in the schemes financed by Imperial Council of Agricultural Research. The Institute and its staff have been recognised by universities in India as a place from which theses for higher degrees can be submitted and a few students and members of staff have obtained their degrees on the basis of the work done at the Institute. The Institute now confers the Associateship of the Institute on those post-graduate students who satisfactorily complete their two-year course.

Research.—The research work of the Institute aims at results of economic value to the country and at the advancement of agricultural science. The subjects selected for investigation are those which are considered to be of importance to the country as a whole. The problems range from those found in old agricultural districts, such as questions of improvement of existing crops and practices, restoration and maintenance of fertility, to those concerned with the introduction of new crops and practices and with the management of new lands or irrigation projects.

Two misfortunes prevented steady application and continued progress. The first was occasioned by the great war which necessitated the drafting of a number of workers for military work; the second was the great Bihar earthquake which put the Institute out of action almost entirely.

The work of the Institute during the three decades may be divided into two periods :—

(1) the period of organisation of the Institute and studying the adaptability to Indian conditions of practices well established elsewhere ;

(2) the period in which definite steps were taken to evolve lines of work suited to the soils, climate and methods of farming in the country.

Sections and their laboratories had to be established, technical men had to be appointed and their assistants had to be trained. When these research facilities became available, it was possible to plan experiments, devise apparatus, methods and other expedients for the collection of facts ; and as facts accumulated they had to be classified and interpreted before they were ready for trial in the field, which is the ultimate deciding factor of the usefulness or otherwise of an improved strain of seed or treatment.

In the pioneering stage of the work, it appeared logical to direct attention to the establishment of practices found successful elsewhere. It was soon learnt that this line of advance was not likely to yield fruitful results. For example, the use of power implements, deep ploughing, heavy applications of fertilisers did not prove generally successful. Crop responses were either poorer than the normal or the increase did not pay the cost of treatment. In some instances entire failure of a paddy crop resulted when heavy paddy lands were ploughed in summer for growing green manure and ploughing it into the soils. These and similar failures brought the recognition of the fact that they were dealing with soils and systems several centuries old and that research should concern itself more with the study of the existing methods and improvements on them.

Definite steps were accordingly taken, and in the second stage of the work the Institute at Pusa developed on the following lines with conspicuous success :—

1. Original research work or verification of experiments on the science of soils, plants and animals.
2. The evolution of improved varieties of crops and the study of conditions suited to their adaptation.
3. The pests and diseases to which crops are subjected and remedies for the same.
4. The comparative merits of rotational cropping and scientific considerations underlying them.
5. The chemical composition and the effect of natural and artificial manures on soils, plants and animals.
6. The relation of soil microbiological population to soil fertility.
7. The role of leguminous and other crops in nitrogen fixation.

8. The study of the scientific and economic questions involved in the utilisation of agricultural produce and waste.

3. The progress made

Brief reviews on the progress of scientific study and experiment during the three decades are appended to this report (pp. 15—90). These studies have done more than add to our knowledge of the nature of the mature soils, of crops growing on them, and of the insects and diseases that attack and destroy the crops. The results of the studies have been of material assistance in improving the agriculture of the country. Without traversing the ground covered by these reviews, the discussion will be confined to the progress made by the Institute in its efforts at increasing agricultural production. All the research work and experiments have been directed towards definite practical ends—cattle improvement, mixed farming and increase in the general level of crop yields.

Cattle Improvement.—Substantial results have been obtained in cattle improvement. The pedigree herd of Sahiwal cows is an example of the results of careful selection, breeding and feeding. Starting in the year 1914 with an average of 5 pounds of milk per animal per day, gradual increments in milk yield have been obtained and in 1937 the milk yield per cow stands at 21 pounds per day. An important line of experimental work in progress relates to early maturity in cattle. The results obtained so far are encouraging and promise developments of considerable economic importance in cattle breeding.

Mixed Farming.—The Institute realised from the beginning that the way to agricultural prosperity lay in mixed farming, and that Indian agriculture prospered or declined in proportion to its ability to evolve a system of balanced agriculture, *i.e.*, the land and the cattle on it should be able to maintain each other. The investigations on soil fertility have shown that this is possible. By feeding animals with the produce grown on the farm and fertilising the land with the dung and adopting a suitable rotation, it is possible not only to improve the productive capacity of the land and maintain its fertility but also to make the land and cattle self-sufficient. With little or no artificial fertilisers, except phosphates, in addition to the dung produced by the cattle on the Pusa farm, it was possible to increase in fifteen years the productivity of a block of 413 acres, to a point sufficient to maintain 300—350 head of cattle on the grain and fodder raised besides wheat and sugarcane crops and the milk of the milch cattle.

Increase in the general yield of crops.—Marked advances have been made in increasing crop yields. The basic improvement

has been obtained by evolving high yielding varieties of crops through the application of the methods of selection and hybridization. These have been found to be much more successful than the introduction and acclimatization of exotics. This is the most popular of the achievements of the Institute. The cultivator having seen that greatly improved races of crops are forthcoming, has not failed to take advantage of them, and to-day improved varieties of crops are being grown over millions of acres. The present well established results in the production of sugarcanes and wheats with qualities demanded by industry and trade are well known.

Further improvement in the yields of high yielding varieties of crops and maintaining the productivity of the land is sought through the use of manures and fertilizers. Our knowledge of the manurial and fertilizer requirements of farm crops and the adjustment of various manures and fertilizers to the needs of different types of soils has so far advanced that we can use them now without much waste, but there is still much that is unknown. Farming on old, mature and mineralised soils which depend on an uncertain monsoon, is a matter so different from farming relatively younger and virgin soils of other lands. Only by continued investigation and experiment that knowledge can be obtained of the conditions necessary to get the maximum benefit out of land, crops and stock.

What we should know is, how far can increase in crop be obtained by the use of manures and fertilizers, and whether the return will be adequate. Here we are faced with the law of diminishing returns and the limiting factors introduced by the amount of water available or by some other factor which limits crop growth. If successive increments in the cost of production and the accompanying successive increments of profits are plotted, the cost of production rises uniformly with increasing applications. The curve for profits rises steeply up to the first half or one cwt. and then suddenly flattens although crop increases up to twenty-five or thirty per cent are obtained. The cost of fertilizer is a powerful limit on increase in production, and this is particularly so with soils in the arid tracts.

Nitrogenous and phosphatic manures are the ones that matte most, and if these can be obtained cheaply considerable head-way will have been made. The natural processes of nitrogen fixation which must be taking place in the soil appear to be the cheapest means of meeting the nitrogen demand at least partially, and investigations in this direction have shown that the natural recuperative powers of Indian soils are considerably greater than thos in the soils of the more temperate climates, so that it is possibl

to control these processes by simple agricultural practices. Extensive and intensive investigations are necessary before definite working formulæ are laid down to make the soil self-supporting in its nitrogen economy. As for phosphates, simple methods of crushing and treating bones have been developed but their extension depends on the availability of raw bones to the cultivator. Phosphate reserves in the soil can be maintained cheapest by returning to the land what the crops have taken out of it, by feeding the animals. Before the digested food material reaches the land in the shape of dung and urine, about fifty per cent of nitrogen is either retained or wasted by the animal but about ninety per cent of phosphate is eliminated in the dung and reaches the land.

With increase in crop yields the risks of damage by pests and diseases become correspondingly great. Here is again need for knowledge and investigation which cannot be borrowed from wiser countries, for many of our problems are so special.

4. Nutritive value of crops

The problem of crop production has now assumed a new phase. The original need for increase in agricultural output per acre is still there, but the change is in regard to quality. Formerly it was quality demanded by trade and industry. Now it is quality for national diet and hygiene.

It was formerly believed that proteins, carbo-hydrates, fat and water were all that was necessary for a complete diet. Later it was realized that certain mineral salts were also necessary. Subsequent experience revealed the necessity for vitamins without which animals cannot grow and keep healthy. As knowledge of the chemical nature of the various substances used as food increased, it became apparent that a mere study of the total protein requirement presents a feeble view of the complexity of the processes of digestion and assimilation and of certain minute requirements and nice adjustments involved. All proteins have not been found to be of equal biological value—which varied with the nature of the amino-acids of the proteins. The discovery of amino-acids as the building stones for the protein molecule and that these constituents cannot be synthesized in the animal body but have to be given in a pre-formed state, either as plant protein or as the flesh protein of animals that eat plants, has opened fresh fields of enquiry.

All amino-acids are not of the same nutritive value and all foods do not contain all the amino-acids necessary. The workers at the Institute have recently shown that the nature of nutrition given to a plant exercises a distinct influence on the composition

and nutritive value of the crop. The gross composition of the crop, especially the grain, may not vary but the make-up of the several constituents of the crop, particulraly of proteins, appears to alter, leading to a variation in the biological efficiency of the grain as seed and food. It would appear possible that protein metabolism in the plant varies with the nature of the manurial treatment.

The evidence that is available at present is of a suggestive nature. Plant metabolism should be studied to ascertain if it would permit control of soil conditions and manurial treatment, so that the end products of plant metabolism may be to the benefit of the soil, the plant and the animal including human beings. Exact knowledge should become available before devising appropriate agricultural practices, and the knowledge can be obtained only by scientific investigation in which several scientists launch a combined attack over a wide front. A beginning has been made in this line of study in co-operation with medical experts.

III. GENERAL ADMINISTRATION

Charge.—Rao Bahadur B. Viswa Nath continued to officiate as Director of the Institute throughout the year. The post of Joint Director was held by Mr. Wynne Sayer up to the 27th May 1937 when he proceeded on leave *ex*-India after handing over charge to Dr. Hem Singh Pruthi, Imperial Entomologist.

Honours.—The year 1937 opened with double distinction for the seniormost Head of a Section of this Institute. Rao Bahadur Venkataraman, Sugarcane Expert, was gazetted a C.I.E. on New Year's Day and was elected General President of the Session of the Indian Science Congress held at Hyderabad (Deccan) in the 1st week of January. The Rao Bahadur is the first Indian member of Agricultural Services in India to be honoured in either way.

Staff.—The post of Imperial Economic Botanist, which was rendered vacant by the premature death of Dr. F. J. F. Shaw, was filled, on the recommendation of the Federal Public Service Commission, by the appointment of Dr. B. P. Pal, Second Economic Botanist, who assumed charge as full Head of Section with effect from the 5th April 1937.

Mr. L. D. Galloway proceeded on leave for two months and five days before resigning the post of Imperial Mycologist to which he was recruited from England in December 1934. Pending appointment of a successor, Dr. M. Mitra was placed in charge of the Mycological Section with effect from the 13th December 1936. When Dr. Mitra took leave for a month and a half from June 16 1937, Dr. B. B. Mundkur was in charge of the Section.

During the absence on leave of Mr. Wynne Sayer, Mr. Arjan Singh assumed charge of the Agricultural Section with effect from the 28th May 1937.

The Chemical and Entomological Sections and the Sugarcane Station remained throughout the year in charge of their permanent Heads, *viz.*, Rao Bahadur Viswa Nath, Dr. H. S. Pruthi, and Rao Bahadur Venkataraman.

The retirement of Mr. L. S. Joseph from the post of Cattle Superintendent, New Delhi, the confirmation of Mr. S. M. Jamaluddin as Cattle Superintendent, Agricultural Substation, Karnal, the conferment on Dr. M. Mitra, Assistant Mycologist, of the D. Sc. degree of the London University, and the recruitment of Dr. K. B. Lal as Second Assistant Entomologist, *vice* Dr. Taskhir Ahmed appointed Assistant Entomologist, deserve mention so far as the Class II Service is concerned.

Schemes of Research financed by the Imperial Council of Agricultural Research.—The following nine schemes were in operation during the year :—

(*a*) *The Botanical Substation, Pusa.*—Originally started at Karnal in October 1930 for the testing of crop varieties too late in maturity for growth at Pusa and for yield trials under canal irrigation, the substation has been moved to Pusa for work under north-eastern conditions on the transfer of the main Institute to Delhi. The scheme is under renewal for five years from October 1935.

(*b*) *Potato Breeding Scheme for Northern India.*—The main object of the Scheme, which has been sanctioned for five years from 1st April 1935, is the production of new varieties with desirable characters such as immunity or high resistance to blight and virus diseases, good keeping quality, etc. Simla has been selected as the site of the breeding station for which land and buildings have been acquired since the close of the year.

(*c*) *Scheme for breeding rust resistant wheats.*—This is an adjunct of the main scheme for the investigation of cereal rusts which is in progress since April 1930, and the breeding work is being carried on in collaboration with Dr. Mehta. Initiated in April 1935 for three years, the scheme is due to expire in March 1938, and the Council has been approached for a further lease of life.

(*d*) *Scheme for research on cigarette tobacco.*—Work in connection with this five-year scheme commenced in August 1936. A compact block of about twenty acres has been acquired near Guntur for establishment of a substation where breeding, manurial and curing experiments are to be carried out. A study of the leaf-curl disease of tobacco forms part of the scheme, and this is being done for the present at Pusa.

(*e*) *Sugarcane Substation, Karnal.*—Established in 1931 to provide the Sugarcane Expert with a farm under his own control for the purpose of testing under Northern India conditions the seedling canes bred at Coimbatore, the Station has for the present been sanctioned up to March 1939.

(*f*) *Scheme for research in genetics of sugarcane.*—Cytogenetic studies are being carried out at the Sugarcane Station, Coimbatore, since May 1934, under this scheme which has been sanctioned for five years.

(*g*) *Scheme for research on mosaic and other diseases of sugarcane.*—This scheme, which was in the first instance sanctioned for three years, began to function at Pusa in June 1932. With the transfer of the Institute, its headquarters have moved to Delhi and the present term is due to expire in May 1939.

(*h*) *Scheme for research into insect pests of sugarcane.*—This is a new three-year scheme which came into operation in 1936 with headquarters at Delhi. Part of the work is carried on at Karnal, Pusa and Coimbatore. The Biological Control Research Officer, who is to be recruited by the Federal Public Service Commission, is yet to be appointed.

(*i*) *Scheme for research into chemistry of sugarcane.*—Started in May 1937, this three-year scheme functioned for less than two months during the year under report. Steps have been taken to recruit an Assistant Sugarcane Chemist in Class II Service through the Federal Public Service Commission.

Training.—The post-graduate courses beginning in November 1936 attracted a record number of 68 candidates, of whom 36 were recommended by Provincial Authorities for nomination of students. Seventeen applicants were selected for admission : four in Botany, five in Agricultural Chemistry, two in Entomology, one in Mycology, three in General Agriculture and two in Sugarcane Breeding who were asked to join the Sugarcane Station at Coimbatore. Of the 15 fresh men admitted at Delhi, two, one each in Agricultural Chemistry and Botany, left after the first term on getting appointments. During the year under report eight post-graduate students successfully completed the two-year course and qualified for the Institute Diploma : three in Botany, three in Agricultural Chemistry, n Entomology and one in Mycology. The one-year course in farm organization and general farm engineering was completed by three students.

In addition, three employees of the Agricultural Department in Baluchistan, one of the Assam Agricultural Department and one of the Sind Agricultural Department were given training for varying periods. A nominee of the Director of Agriculture in Sind and

a private candidate from the Punjab University were also admitted as shortcourse students. Five post-graduate students of the Imperial Dairy Institute, Bangalore, were given facilities for studying the work done at the Institute and its substation at Karnal.

A special course in the flue-curing of tobacco lasting for two months was organized at Pusa during the winter of 1937. It was attended by one candidate each from Madras, the Punjab, the United Provinces and Indore State.

The Overseer incharge of the Cattle Farm, Bharari (U. P.), who was accompanied by a Fieldman and 10 Herdsmen, a Naik and a Rifleman of the 9th Gurkha Rifles, and a Veterinary Assistant from the Punjab, received training in the methods of cattle management adopted at the Institute.

Mr. S. V. Ramanaya, who was awarded the M.Sc. degree of the Andhra University for his work done at this Institute on "Chemistry of sulphitation process of sugar manufacture as applied to coloured sugarcanes", presented the same thesis and won the second prize of Rs. 500 awarded by the Advisory Council of Industrial Intelligence and Research.

Library.—Publications received in exchange numbered 3,998, while 341 were purchased. As the Library had to be closed for the transfer to New Delhi, the issue of books on loan remained suspended for the major part of the year. Over 800 books were, however, issued on loan, of which nearly 100 were sent to scientific workers in the Provinces and Universities.

IV. ACCOUNTS

The total expenditure of the Institute and its out-stations at Karnal and Coimbatore during the financial year ending 31st March 1937, amounted to Rs. 8,74,050, inclusive of the cost of the transfer of the equipment of the Institute which amounted to Rs. 1,28,042.

Name of Establishment	Expenditure
	Rs.
General expenditure of the Institute including the office of the Director, Power and Gas Plants, the Medical and Estate Establishments, and cost of the transfer of the equipment of the Institute	2,97,564
Agricultural Section	1,65,110
Botanical Section	40,504
Chemical Section	71,946
Entomological Section	61,767
Mycological Section	41,845
Agricultural, Sub-Station, Karnal	58,486
Sugarcane Station, Coimbatore	94,109
Petty construction	42,719
	8,74,050

The expenditure on the various research schemes financed by the Imperial Council of Agricultural Research amounted to Rs. 88,376 as shown below which was met from the funds of the Council :—

	Rs.
(*a*) Research on mosaic and other diseases of sugarcane .	19,104
(*b*) Research on insect pests of sugarcane	10,399
(*c*) Research on genetics of sugarcane	6,414
(*d*) Sugarcane Sub-Station, Karnal	12,540
(*e*) Tobacco Breeding Sub-Station, Guntur . . .	6,647
(*f*) Potato Breeding Sub-Station, Simla . . .	7,682
(*g*) Botanical Sub-Station, Pusa	25,590
Total .	88,376

The receipts of the Institute and its out-stations amounted to :—

	Rs.
Main Institute	40,194
Agricultural Sub-Station, Karnal	14,040
Sugarcane Sub-Station, Coimbatore	8,202
Total .	62,436

2. THREE DECADES OF AGRICULTURAL RESEARCH AT THE INSTITUTE

(*a*) GENERAL AGRICULTURE INCLUDING ANIMAL HUSBANDRY

(WYNNE SAYER IMPERIAL AGRICULTURIST)

The work on farm practice started from the year 1904. The main lines of investigation have been the testing of various manures and of field crops, including sugarcane and different fodder and forage crops. Considerable work has also been done on crop rotations, mechanical cultivation, testing of bullock and power-driven implements and on the design of suitable implements and farm equipment for Indian conditions. Another important feature has been the work on the pedigree Sahiwal herd which has been gradually improved by selective breeding. In the following pages, an attempt has been made to review and summarize the work done on the lines indicated above.

CROP EXPERIMENTS

CEREALS AND LEGUMES

Varietal trials with a large number of crops over a period of several years have demonstrated definitely high-yielding capacity of the following varieties produced by the Institute :—

Crop	Variety
Maize	Pusa Farm No. 3
Gram	,, No. 11
Soybean	,, No. 2
Peas	,, Nos. 2 & 3
Wheat	Botanical Section Type 52
Barley	,, Type 21
Oats	,, Nos. 1 & 2

Of the above, the varieties of soybean, wheat, barley and oats are still in great demand and are being widely distributed.

FODDER AND FORAGE CROPS

At Pusa, a great deal of work has been done in the past 15 years in connection with fodder problems, and a large number of fodder grasses from all parts of the world have been grown and tested.

The work on imported fodder grasses has led to the same result, namely, that they do well in the monsoon when there are other fodder grasses in abundance, but they are of no value in the hot weather and in winter when there is no other

grass available. After a thorough trial, berseem has proved to be the best irrigated winter fodder crop for the milch herd, and *gaur*, cowpeas, *meth*, and soybean as hot weather and monsoon fodders. At Pusa, the whole herd (about 400 head) was maintained on 120 acres of sandy *dhab* (low-lying) land cropped with hot weather maize and berseem in rotation. The improvement of this *dhab* land after 15 years under berseem cultivation was very marked, as it was able to hold an unmanured sugarcane crop successfully.

After a number of years' trial, the following grazing cycle of green fodders was found suitable for the dairy herd at Pusa and is being followed now at New Delhi also :—

Crops	Months
Guar (*Cyamopsis psoralioides*)	August
Cowpeas	September
Meth (*Phaseolus aconitifolius*)	October
Soybean	November
Berseem	December to April
Maize and *Meth*	May to July

Extensive investigations have also been carried out at Pusa on silage making, and it was found that maize silage suits the dairy animal better than any other silage. Berseem has also been made into good silage without any appreciable loss of food units.

Sugarcane

Work on sugarcane received careful attention from the very beginning. During the last 20 years we have tested out more than 300 varieties of cane, and from here the original selection and distribution of the famous canes Co. 210, Co. 213, and Co. 214, was made by which the Indian sugar industry was saved and subsequently has been built up to its present size. Subsequent successful selections were Co. 281, Co. 285, Co. 299 and Co. 331.

The important characters of these varieties as grown under Pusa conditions are briefly given below :—

Co. 210.—Medium cane, does well on light land and in years of short rainfall. Tonnage yield per acre, 600 to 700 maunds ; sucrose per cent in juice, 16·90 in February.

Co. 213.—Medium cane, gives maximum yield in heavy soil and in years of good rainfall. Tonnage yield per acre, 600 to 700 maunds ; sucrose per cent in juice, 17·96 in February.

Co. 214.—Thin, early-ripening cane with comparatively lower tonnage yield. Tonnage yield per acre, 400 to 500 maunds ; sucrose per cent in juice, 15·97 in November.

Co. 281.—Medium thick cane ; does well in years of heavy rainfall. Requires 2 to 3 irrigations in the hot weather. Tonnage yield per acre, 700 to 750 maunds ; sucrose per cent in juice, 17·32 in December.

Co. 285.—Thin to medium cane ; suitable for lighter lands and low-lying places. Tonnage yield per acre, 600 to 650 maunds ; sucrose per cent in juice, 16·54 in December.

Co. 299.—Medium early ripening cane with better tonnage yield than Co. 214. Tonnage yield per acre, 500 to 600 maunds ; sucrose per cent in juice, 15·33 in November.

Co. 331.—Thickish cane ; grows well in heavy and light soils. It is able to stand late in the field without deterioration. Tonnage yield per acre, 750 to 900 maunds ; sucrose per cent in juice, 17·06 in April.

The technique of sugarcane cultivation has been considerably developed, and by the improved Pusa method of cultivation (described below), it is now possible to obtain a higher yield at a cheaper cost than before. This method is being adopted at Delhi also with good results.

The land for cane plantation is green-manured in the preceding *kharif* (monsoon) with sunn-hemp to which double superphosphate (40 per cent P_2O_5) is added at the rate of 2 maunds per acre. The soil is worked thoroughly during the *rabi* (winter) and kept closed to retain moisture. At the time of planting, furrows are opened with a double mould-board plough fitted with a sub-soiler working directly behind it. The distance between the rows varies according to varieties—3 feet in the case of medium and thick, and $2\frac{1}{2}$ feet for the thin canes. Before planting, oilcake meal (5 per cent N) at the rate of 10 maunds per acre is spread evenly in the furrows. After the cane setts have been placed " eye to eye ", the soil gatherer with roller is drawn over the furrows, filling them up, covering and pressing the setts.

The intercultural operation is started just after the germination of cane. The work is done cheaply and satisfactorily with a cultivator which is drawn by a pair of bullocks between the rows. The operation is repeated several times till the break of monsoon when the crop is finally ridged up with the double mould-board plough. No further operations are required till the time of harvest.

For intercultural and ridging operations on a large scale, a "Farmall " tractor (row-crop type) has been found suitable.

ROTATIONAL EXPERIMENTS

The principal crops grown on the Pusa Farm were maize in the *kharif* and *rahar* (*Cajanus Cajan*), oats and gram in the *rabi* season.

They were intended to provide feed for the dairy herd and other livestock maintained on the Institute Estate. These crops were grown without irrigation. The following rotation was practised over the greater part of the Farm :—

Season	1st year	2nd year	3rd year
Kharif (Monsoon) .	Maize for fodder and silage	Maize for corn	Legumes for grazing
Rabi (Winter) .	Oats . . .	*Rahar* and gram	Oats

The rotation had run long enough to prove its suitability for the Pusa soil. The yield obtained from different crops in different years showed that the fertility of the land was considerably increased under such rotation.

MANURIAL EXPERIMENTS

Permanent Manurial and Rotation Experiments

These experiments were laid down at Pusa in 1908 according to the scheme formulated by the Board of Agriculture with a view to study the conditions which determine soil fertility and the manner in which soil fertility is affected by the application of important manures, including green manures, and by rotation of crops. A sub-committee of the Board of Agriculture held in 1929 examined the question of the continuance of these experiments and made certain alterations in the scheme which have been followed since 1930-31. The results of these experiments are summarized below.

(*a*) *Effect of organic manures.*—(*i*) Bulky organic manures had a very appreciable effect in increasing the total crop, but whereas, with cereals, the production of grain was materially increased, the reverse was the case with *rahar*. (*ii*) The residual effect of the rape cake was inappreciable on the second crop although its effect on the crop to which it was applied was very marked. Rape cake was, therefore, not as effective as farmyard manure when the application was made only once in a full cropping season.

(*b*) *Effect of mineral manures.*—(*i*) Of the manurial constituents, nitrogen, potash and phosphoric acid, when applied alone, the latter was the only one which gave a distinctly positive reaction in the Pusa soil, but the combination of all three gave the best results with the crop to which it was applied. (*ii*) In the case of cereals, the use of phosphoric acid increased the proportion of grain, but in the case of *rahar* all manures increased the proportion of green matter.

(*c*) *Effect of green manures.*—The effect of green manures on cereals was definite and distinct, and still more so when in combination with phosphoric acid. The yield of *rahar*, however, decreased under the influence of both green manure and phosphoric acid.

Other Manurial Experiments

(*a*) *On cereals and legumes.*—Rapecake, farmyard manure, superphosphate, ammonium sulphate and potassium sulphate were tried singly and in various combinations on maize, oats, wheat, peas and gram. With cereals, it was found that (*i*) rape cake, (*ii*) farmyard manure, (*iii*) ammonium sulphate with superphosphate and potassium sulphate and (*iv*) ammonium sulphate with superphosphate, gave better results than other treatments, whether alone or in combinations, while potassium sulphate had a decidedly depressing effect. With peas and gram, the results were similar with the difference that the plots treated with superphosphate alone gave equally good yield.

(*b*) *On sugarcane.*—Of the important manures and fertilizers which were tried on sugarcane at Pusa, (*i*) farmyard manure at the rate of 14 tons per acre and (*ii*) green-manuring with sunn-hemp followed by superphosphate at 50 lb. P_2O_5 per acre and rapecake at 40 lb. N per acre promoted maximum yield of this crop. Further, it has been observed that there is no deterioration in the quality of juice by the application of these treatments.

(*c*) *Green-manuring experiments.*—Green-manuring experiments with sunn-hemp, cowpeas, soybean, velvet bean, *meth* (*Phaseolus aconitifolius*) and *guar* (*Cyamopsis psoralioides*) were conducted on wheat. Plots green-manured with sunn-hemp, cowpeas and velvet bean gave significantly more yield than others.

MACHINERY AND IMPLEMENTS

Test and Design of Machinery and Implements

The testing of agricultural machinery at the Institute has included both mechanical and animal-power driven machines manufactured in India or abroad. From a large number of tractors and tractor-drawn as well as bullock-drawn implements tried so far, it has been found that any attempt in the reduction of initial cost of an implement, be it Indian or foreign made, results in the use of inferior material and consequent breakdown of the implement, often in the very first year of its use. On the other hand, many strongly built implements, although somewhat costly at first, have lasted for nearly a quarter of a century or so without much subsequent repair.

After conducting a large number of trials, the following machines and implements have been recommended to interested farmers and planters with confidence.

(1) *Tractors*

(*a*) *McCormick Deering, 15/30 H. P. kerosene-oil tractor.*—This tractor has been on trial since 1927-28. From an examination of the data accumulated during the past years, the following figures regarding its working cost, output of work and other expenses have been arrived at: ploughing per hour, 0·95 acre; cost of ploughing per acre, Rs. 4-2-9; fuel and oil consumption per hour, 2·46 gallons; cost of spare parts per hour, Re. 1-0-4; and total expenses per hour, Rs. 3-10-5.

(*b*) *Lanz Bulldog, 15/30 H. P. crude-oil tractor.*—This tractor has been working very satisfactorily since 1930-31. Details of working cost, etc., are as follows: ploughing per hour, 0·81 acre; cost of ploughing per acre, Rs. 3-0-9; fuel and oil consumption per hour, 1·83 gallons; cost of spare parts per hour, Re. 1-0-6; and total expenses per hour, Rs. 2-9-7.

(2) *Tractor Implements*

(*a*) *Plough.*—Ransomes' Consul series. 3-furrow, 4-furrow and 5-furrow mould-board type.

(*b*) *Disc-harrow.*—Ransomes' Baron tandem and Baronet types; sizes 8 ft. and 10 ft.

(*c*) *Cultivator.*—Ransomes' Orwell 11-tine, and International 13-tine, field cultivators.

(*d*) *Seed drill.*—Amsco self-lift disc coulter, 8 ft. wide.

(*e*) *Silage cutter.*—International, Types B and E. The Type E is identical with Type B excepting that it is smaller and has four lengths of cuts instead of the eight in Type B and has two knives instead of the three in the latter. The Type B is suitable for and works efficiently with steam power, while the Type E is better used with tractors.

(3) *Bullock Implements*

(*a*) *Plough.*—Ransomes' all-steel Victory. This is a simple light plough which is easy to draw. The plough body is built on a pressed steel bottom which firmly holds together the breast, share and land-side, and is rigidly fixed to the beam. The plough is provided with two handles made of steel specially hardened and tempered. It will plough a furrow 3″ to 6″ deep and 6″ to 10″ wide.

(*b*) *Cultivator.*—Raja spring tooth harrow. It is represented by two types—5-tined and 7-tined harrows. Both are most durable

and strongly built. The tines which are all steel are adjustable for depth and pitch by means of a hand lever. They are provided with reversible and renewable points which can be adjusted to work for any depth between 1″ to 4″.

(*c*) *Cultivator.*—Planet Junior Indigo cultivator. This is a light and simple implement fitted with 5 tines. Where earthing up is not required, this is a useful implement for ordinary interculture. The width may be adjusted by means of a set screw.

(*d*) *Cultivator.*—Parmiter chain harrow. This flexible chain harrow is a useful implement for collecting weeds and stubbles especially in a double-cropping system where one crop immediately follows the other, and the weeds have to be removed before the second crop is sown. It is also useful for making a fine surface tilth, for covering seed after drilling, for breaking crust after a shower of rain but before the germination of seeds, and also for working over grass-lands.

(*e*) *Cultivator.*—Brandford weeder. A very useful implement for breaking light crust formed by rain after sowing crops.

(*f*) *Seed drill.*—Gujrat type. This is a country-made implement and sows efficiently all crops which are grown in rows, specially maize and cotton. Seeds can be sown in rows from 2 to 4 feet apart.

(*g*) *Land leveller.*—Sindhi type made at Pusa. This implement is most useful for levelling, terracing and making bunds. When full of earth, it is tipped, and the rope between the handles rests on the draught chain. This is far more efficient than the simple levelling plank.

(4) *Carts*

Wooden bodies designed at Pusa have been fitted with the Dunlop pneumatic equipment. Pay load carried is 50 maunds as against 25 maunds by ordinary country cart.

(5) *Threshing machine*

To meet the needs of the average farmer, a bullock-gear thresher and a winnower have been designed at Pusa. They have proved quite efficient and satisfactory. The complete set costs :—

	Rs.
Thresher	450
Bullock gear	335
Winnower	230

The output is $3\frac{3}{4}$ maunds clean wheat grain per hour at a cost of about $5\frac{3}{4}$ annas per maund as compared with 8 annas per maund by the ordinary treading method. The bullocks while working the gear convert the straw into *bhusa*.

The effect of the speed of cultural implements on the tilth of soil

It has been found in the course of tractor trials that the draw-bar pull changes but little for a large change in speed, and the increased fuel consumption required for this purpose is insignificant as compared with the saving in labour and time as a result of the increased speed. Such increased speed, therefore, results in a considerable saving in expenses.

At present, a large amount of wear and tear is set up in tractors designed for a ploughing speed of 2½ m. p. h. when used constantly at 5 m. p. h. But this is purely a question of alteration in design to suit the altered conditions, and as such alteration in design, if proved definitely economical and of use to the farming community, can undoubtedly be regarded as well within the scope of the agricultural engineer.

To find out whether increased speed has any detrimental effect on the quality of work, *viz.*, the tilth of the soil, crop yield, etc., three experiments were conducted at Pusa. The experiments were laid down on a replication system with two treatments—(*i*) ploughing and harrowing at 2½ m. p. h. and (*ii*) ploughing and harrowing at 5 m. p. h. At the faster speed, the field was more finely broken which greatly simplified subsequent harrowing operations. Moreover, no gaps were left unploughed, and the quality of the seed-bed formed was similar to that formed by working the implement at normal speed. The difference in crop yields obtained from plots ploughed at fast and slow speeds was not statistically significant.

Bullock plough experiment

In order to obtain definite data as to the effect of different ploughs on the tilth and crop yield, an experiment was carried out at Pusa in a field with medium light soil.

Four light turn-over ploughs, *viz.*, (*i*) Pusa made bar plough, (*ii*) Hindustan plough, (*iii*) Shanti plough and (*iv*) Bihar plough, designed to be improvements over the country plough, together with the Ransomes' all-steel Victory plough (turn-over) and the country plough (non-turn-over), were allotted a plot of half an acre each to be separately cultivated. The cropping scheme followed was maize and peas in the first year, maize and barley in the second year, maize and *arhar* in the third year and maize and wheat in the fourth year.

The results obtained after four years' trial establish the superiority of the Ransomes' Victory plough to all other ploughs, the Pusa made bar plough coming next to the Victory plough.

CATTLE BREEDING & DAIRYING

Work on the Sahiwal Milch Herd

Improvement of milk yield

(*i*) *Selection.*—The Pusa pedigree Sahiwal herd has been in existence since 1904 when 14 cows and 1 bull were purchased from the Punjab. It has since been gradually selected up from the home bred stock with fresh blood from occasional outside purchases. The average milk yield per cow per day has risen from 5·8 lb. in 1913-14 to 21·2 lb. in 1935-36 as shown below :—

Average milk yield per cow per day in lb.

Year	Annual average	Year	Annual average	Year	Annual average
1913-14	5·8	1921-22	8·0	1929-30	12·4
1914-15	7·5	1922-23	9·4	1930-31	13·0
1915-16	8·3	1923-24	10·8	1931-32	13·6
1916-17	6·6	1924-25	11·1	1932-33	17·9†
1917-18	6·8	1925-26	12·3	1933-34	18·7†
1918-19	6·1	1926-27	11·7	1934-35	19·1†
1919-20	7·4	1927-28	12·7	1935-36	21·2†
1920-21	8·3	1928 29	14·3*	1936-37	20·7†

*Best year under two times milking. †Four times milking.

Some of the best milk records of cows and heifers are given below :—

	Year	Name and No.	Milk yield (lb.) per lactation	Lactation period (days)
Cows	1925-26	Kamli . . 312	7,053	306
	1932-33	Ajbi . . 567	8,060	306
	1934-35	Chandrika. . 482	8,549	304
	1935-36	Atuly . . 480	9,012	304
	,,	Ramati . . 566	9,272	305
	,,	Adami . . 503	9,357	306
	1936-37	Chansuri . . 653	10,119	306
	1937-38	Laruli . . 604	11,003	304
Heifers	1921-22	Kamli . . 312	5,785	304
	1932-33	Lalagi . . 596	7,019	306
	,,	Laruli . . 604	7,648	304
	1935-36	Chansuri . . 653	7,685	305

(*ii*) *Four times milking.*—Upto March 1932, the cows in the Dairy were milked twice daily in the morning and evening. Thereafter, as an experimental measure, milking four times daily at an interval of 6 hours was started. This treatment has contributed to the increase in milk yield recorded above.

(*iii*) *Pre-milking and training to milk.*—The udder trouble in the herd, which good milch cows of this breed frequently get due

to heavy secretion of milk prior to calving, has been avoided by milking the cows 7 to 10 days before calving.

Heifers and cows not milking upto the standard of 4,000 lb. per lactation have been now trained to give more milk. The process consists of massaging the udder about two months before calving and thus accustoming them to being handled. When the flow of the milk starts, the cow is milked out each day. After calving she is milked 7 to 8 times in 24 hours until she gives down. By this method, cows much below standard have been gradually brought up to yield heavily.

Early Maturity Experiments

Experiments to bring about early maturity in the progeny of the herd were started at Pusa in 1932. In the Sahiwal breed, the heifers do not take the bull till they are 2½ years old and the bulls are not able to serve before the age of 3 years. This late maturity of heifers and bulls has been a great obstacle in the introduction of proved bulls, because one had to wait for about 9 years to know the performance of their progeny. Early maturity has been successfully induced by special feeding and we have now got bulls serving at 1 year and 7 months and heifers taking the bull at the age of 1 year and 6 months to 1 year and 8 months. In all these cases, the progeny are normal and as healthy as those bred from the older stock. These results should have a far-reaching effect in accelerating the improvement of milch breeds of cattle.

Impotency and Sterility in the Breeding Stock

The causes of the gradually increasing number of cases of impotency in bulls and sterility in cows in the Pusa Sahiwal herd were under investigation since 1931, and it has been found that in most of these cases impotency was due to over-feeding. Some of these cases which were not amenable to treatment by changed rationing have yielded to hormone treatment which consists of injecting, subcutaneously, detoxicated and neutralized urine of cows eight months and over in calf. This is injected in doses of 10 c. c. for every 100 lb. body weight on four consecutive days, and repeated whenever necessary after three weeks.

WORK ON CROSS-BREEDING

The first pedigree Ayrshire bull was purchased in 1914 and was put over the poorest milkers in the Sahiwal herd. The average yield of half-bred cows per lactation period was 6,974·2 lb., while that of their dams averaged only 2,543·2 lb. The first hybrids undoubtedly proved good dairy animals, but the further crosses were disappointing. The work was, therefore, stopped in 1930.

(*b*) BREEDING IMPROVED TYPES OF CROPS

(i) Sugarcane

(T. S. VENKATRAMAN, SUGARCANE EXPERT)

INTRODUCTION

For a clear understanding of the note that follows on the scientific activities of the Sugarcane Breeding Station, Coimbatore, during the two decades and a half of its existence, it is necessary to indicate here in a few words the nature of the canes in cultivation in India and the condition of the Indian Sugar Industry about the time of the inception of the Station in October 1912. It was a time when the very existence of the crop in the main cane provinces of India was threatened with extinction from the import into the country of large quantities of sugar from outside. The very efficient sugar industry built by Java, partly relying on India's needs, was growing from success to success both on the agricultural and manufacturing sides. The Indian industry, on the other hand, had touched almost the bottom in its steady decline in the matter of yields.

Poor class of canes.—It was widely held at the time that the Indian sugarcane crops had no chance against the highly bred and specialised crops of the tropics which often yielded under their own conditions four to six times of that in India. All attempts at importing foreign tropical canes into the main Indian cane regions proved futile as they would not grow under these conditions. The indigenous canes, on the other hand, which dominated the cultivation, were so thin, so reed-like and so primitive that it is no wonder their possibilities were held at a discount. Even the original founder of the Station, Dr. C. A. Barber, C.I.E., wrote to the " Times " of London, immediately after his retirement in 1919, pointing out the various disadvantages associated with the Indian conditions for cane growth, and this note was far from optimistic about the future of the Indian industry. Later, when the practical results of Coimbatore work became available the late Dr. Barber wrote on more than one occasion expressing pleasant surprise at the results achieved.

Long probation period.—A second feature associated with the activities of the Coimbatore Station has been its long temporary footing for a period of well nigh a decade and a half. As this happened to coincide with financial depression in the country, it was frequently hauled up before Retrenchment Committees in a desire to save expenditure by a complete shut down of such non-permanent commitments. This state of affairs placed a severe strain on the officers at the Station and resulted in a constant endeavour

to hustle and show tangible results to justify the existence and continuance of the Station. It is doubtful if the Station, whose activities form the subject of this note, would have lived beyond these dark days, if the crop had been one other than the sugarcane or the methods adopted not so thoroughly practical and with a view to economic results as they had been. As it is, however, it is pleasant to record that the activities of the Station have materially contributed to converting India from a major sugar-importing country to the tune of one million tons at the time of its inception, to the present position where she is looking out for possible export markets.

THE BREEDING PROGRAMME

Short growth period.—It has been mentioned that the growth conditions in the Indian cane area differ in important respects from those obtaining in other tropical sugarcane countries of the world. Till the Indian canes came to be known to the outside world, the term " sugarcane " indicated largely the tropical type and most sugarcane work outside Coimbatore had been largely on this type. One important handicap in the growth conditions of the Indian sugarcane area (largely sub-tropical) is the very short period available for growth. The canes are generally planted in February-March and start life under extremely severe summer conditions that greatly inhibit growth. It is only with the monsoon rains of June-July that the crop gets any real chance to grow. At the other end, a fairly severe winter—accompanied by frost in the western regions—practically stops growth from the end of November. It may be stated that the total growth period corresponds roughly to only about six months of normal growing. In the tropical parts of the world, on the other hand, sugarcanes can grow almost uninterruptedly for twelve to sixteen months and in Hawaii even to twenty-four months. This renders the problem of cane-breeding for India of a special if not also of a somewhat difficult nature.

Extremes of climate.—A second environmental condition which also renders cane-breeding for India comparatively difficult is the extremes in climatic conditions that the crop passes through in its life-cycle from very high temperatures and severe drought in summer to comparatively low temperatures, including frost, towards harvest. In certain places flooding during the monsoon rains introduces yet a third adverse factor for growth. All these have had a direct bearing on the nature and number of parents employed for securing the improved types. They also explain why previous importations from outside India had proved failures so far as the main sub-tropical sugarcane belt of India is concerned.

Range of parents.— One outstanding characteristic of the breeding work at Coimbatore has been the range of parents it has been able to employ in its breeding programme. It was the first Sugarcane Station in the world to deliberately employ *Saccharum spontaneum* and to raise an intergeneric hybrid with *Saccharum* (*Saccharum* × *Narenga narenga*). It has also been able to bridge in intergeneric hybridization the widest disparity (between the genera) both in morphological characters and in taxonomic position in the two recent hybrids, *viz.*, *Saccharum* × *Sorghum Durra* Stapf. and *Saccharum* × *Bambusa arundinacea* Willd. It was led to such work by the difficult and rather unusual growth conditions in the Indian cane area. The negative results through breeding from the Indian canes (*S. barberi*) and the unsuitability to North Indian conditions of types bred from *S. officinarum* turned its attention to other parents. It was early realised that success would depend directly upon the number and range of parents employed and certain of the popular Coimbatore canes include in their parentage three different species of *Saccharum*.

THE WILD SACCHARUM

The collection and study of wild *Saccharums* has been a constant item of work among the activities of Coimbatore. It was but in the fitness of things that it should be so because of the somewhat difficult conditions for cane growing in the country. Particular mention needs to be made here of the various types of *S. spontaneum* ranging from a dwarf form in the Punjab, hardly two feet high, to others in Assam and Burma measuring twelve to fifteen feet and not much removed from the Indian canes of the *S. barberi* group in field characters. One such type has recorded sugar higher than certain of the Indian canes of the Punjab and the United Provinces. The range of forms has been so great as to indicate India as one of the original homes of at least one race of sugarcanes. The collection includes types from Burma and the islands of the Eastern Archipelago. The employment of these types has been of considerable use in the production of suitable types combining in themselves considerable growth vigour and resistance to both adverse conditions and diseases. Both the later popular Java canes and the popular Coimbatore productions have fully justified the employment of these forms.

The other type of wild *Saccharum*, *S. robustum*, collected in 1928 by Drs. Brandes and Jesweit from New Guinea, is of a different class and perhaps the progenitor of the so-called ' noble ' or tropical type of canes with which it has a family resemblance.

THE BREEDING TECHNIQUE

The stock in trade for any breeder is the material which he is able to bring together in the form of types possessing different characteristics. Briefly stated, the breeder builds his new types by suitable hybridization between his parents combining in his products the good characteristics of different varieties. The first work attempted at Coimbatore was therefore the collection of cane varieties from all over India and the world.

The sugarcane parents collected at Coimbatore presented quite a series of problems for solution before starting regular breeding. Some of these were (1) the non-flowering of certain parents including even the indigenous canes during their first years of growth at Coimbatore ; (2) the absence of fertility in the floral organs even when the canes did flower ; (3) the disparity in the times of flowering of the parents it was desired to cross with each other ; and (4) difficulties associated with the actual breeding technique resulting from the smallness and delicacy of the floral organs in the sugarcane and the height at which the inflorescences are put forth in the cane.

While certain of these, particularly the sterility of the sexual organs, have not proved amenable to solution, considerable progress has been recorded in most other items each involving detailed and patient work. Planting under certain conditions has succeeded in inducing flowering in certain parents. The planting of canes at different times and under different soil conditions and subjecting the parents to different day lengths have enabled the partial bridging of the disparity in times of flowering. Studies on the germination and preservation of sugarcane pollen, the duration of stigma receptivity, period taken for fertilization in the cane and correlation studies between quality of pollen and anther colour, have materially contributed to the simplification of the breeding technique in many directions. These coupled with the isolation of desired parent canes after artificial rooting have enabled the carrying out of desired hybridizations on a mass scale, a necessary condition to successful cane-breeding.

MORPHOLOGICAL STUDIES

Description of varieties.—The Station at Coimbatore was the first to attempt in suitable botanical language descriptions of sugarcane varieties based on definite and recognisable morphological characters. Previous descriptions of canes were based a little too much on such variable characters as colour of cane and dimensions of organs. As compared with other crops, descriptions of sugarcanes are at a disadvantage on account of the non-inclusion of the inflorescence. This is partly because all canes do not flower

and the crop in cultivation is generally cut and propagated without any reference to its flowering and seed formation. The various parts of the inflorescence—the rachis and its vestiture, the composition of the spikelets, the nature and size of the glume and palea, the essential organs and lodicules—have all been recently receiving attention, partly to follow the inheritance of such characters and partly to detect in the hybrids the influence of pollinating parents.

Classification of canes.—These careful descriptions of cane varieties combined with constant observations of the field characters resulted in the first scientific classification of these canes. It is significant that such classification, originally based on morphological and field characters alone, has since been confirmed by a study of chromosomes, one of the latest developments of botanical science. The group of Indian canes contains some very interesting forms, types similar to which have recently been built by the latest hybridizations at Coimbatore—some of them intergeneric. Other types would appear to have arisen as natural hybrids between different types of *Saccharum* and allied species.

PHYSIOLOGICAL STUDIES

The physiological studies on the sugarcane plant have been associated very directly with the performance and growth of different canes under field conditions. This I consider an important feature of the Coimbatore work and unlike other similar studies where the plant is taken inside the laboratory rooms and studies made under the somewhat unnatural conditions resulting therefrom. The main aim has been to keep the crop growing in the field and follow from time to time its behaviour under the open field conditions. The progress of maturity of canes in the field joint by joint, the mode and rapidity of branching (or tillering)—an important factor in cane yields—the plan of development and depth of roots and the nature of soils best suited to them, are certain of the problems successfully tackled in this line. The development of fibre in the cane and tests for rind hardness with a view to judge liability to animal attacks are other items which have been similarly dealt with.

LIFE-CYCLE OF THE CANE

There has been a constant endeavour to follow the life-cycle of the sugarcanes from germination to harvest, the depth of rooting at different times of the year, the juice contents from time to time and the reactions of the plant as a whole to the different sets of

environmental conditions at different seasons of the year such as summer drought, frost or flooding.

The methods employed in such studies have been fairly simple, often consisting of mere weighments, countings or root dissections in the field. Here again the aim has been to carry the studies in the field, thus correlating them directly with natural growth conditions. The results of such studies have been very useful, comparative simple weighments, for instance, indicating how the plants behaved and reacted during summer. Such studies have been periodic and timed to changes in environmental conditions. To mention just one instance, periodic root studies showed that the depth of roots at the time of frost incidence is correlated with the observed resistance of the variety to frost.

Periodic studies of the life-cycle of the canes have been of great practical use both in the selection of the right types and also in bringing out certain important characteristics of the cane crop. Periodic juice analyses have enabled not only the selection of ' early ' and ' late ' canes but have yielded important indications as to the period during which canes after ripening keep up juice quality without appreciable deterioration. This is a character of great importance both to the grower and to the manufacturer. Here is another instance of the value of concrete and direct relationship between the studies undertaken and the crop as it is growing in the field.

INHERITANCE AND OTHER STUDIES

Inheritance.—In the earlier years considerable time and work were devoted to a study of the inheritance of characters in the sugarcane both from selfed populations and from different kinds of hybrids. The seedlings were examined, in some cases, for as many as over thirty different characters. As no easily recognisable laws of inheritance were revealed in the course of this work, these were abandoned as unprofitable in a Station which had to fight for its very existence solely on economic results. Very interesting data were however obtained particularly when the same pistil parent was hybridised with different male parents.

In-Breeding.—As compared with most other crops, there has been very little ' in-breeding ' in the sugarcane, as such work is often unattended with immediate useful results. At Coimbatore, however, there have been a fair number of examples of in-breeding generally with the object of securing further advances on the improved canes already obtained. From Coimbatore experience the chief value of in-breeding would appear to be likely to be in the direction of accentuating certain characters. It is found that

the products of such in-breeding might need further hybridization to introduce vigour of growth, somewhat lost in the process.

Correlations.—A third obvious line of work for expediting results is the study of possible correlations between morphological and other characters of the plant and the crop characters of the seedlings. Laborious and patient work in this direction proved unprofitable and was consequently given up after the first few years.

Root studies.—Considerable work on the development and characters of ' sett ' and ' shoot ' roots, the factors influencing root development and the location of the live regions of the root system, has been recorded with very beneficial results to the study of the crop as a whole. New ground has been broken in this line of investigations.

CYTOGENETIC STUDIES

Having fulfilled the first essential to its existence, *viz.*, the production of improved canes—over seventy per cent of the sugarcane area in India is under such canes up to date (1936-37)—Coimbatore has been able to divert its attention somewhat to certain fundamental problems associated with the plant. One such is the series of cytogenetic studies that have been in progress at Coimbatore during the last three years and with funds kindly made available by the Imperial Council of Agricultural Research. Properly controlled crosses have been made and are being studied and various interesting features associated with meiosis in the *Saccharum* are revealing themselves. This work is throwing light on the origin and distribution of *S. spontaneum* types, the probable origin of certain Indian canes and similar problems. The large numbers associated with *Saccharum* chromosomes—particularly in the later seedlings—render the work both difficult and time-consuming. A fund of knowledge is waiting to be revealed when, besides the number, the study of chromosome morphology advances further than at present.

METHODS AND APPARATUS

Special features associated with the methods and apparatus employed in the study of the sugarcane plant at Coimbatore have been (1) the cheapness of the apparatus employed, often from cheap country earthenware and other material easily available ; (2) the feasibility of carrying out the studies on quite a large number of plants and in the natural conditions of the open field instead of on comparatively fewer plants inside room and laboratory conditions ; and (3) the studies being made as far as possible on crops growing in the fields. The varied and ingenious devices adopted

in these experiments have been fully described in various publications from the Station. It has been possible, for instance, to raise the tillering process in the sugarcane plant at a fair height above the soil and thus facilitate studies from time to time both with the naked eye and the camera. It has been possible to divide the roots of the plant into equal parts and allow them to grow and develop under different soil and moisture conditions. It has rendered possible the isolation through artificial rooting of a cane after it is definitely known that it will flower and its suitable segregation for efficient and reliable cross pollination.

MISCELLANEOUS

The main lines of work above described threw up during their progress various sundry problems which needed solution before further advance could be registered. Certain of these are mentioned here.

Elaborate experiments were undertaken with the object of evolving a suitable method of packing for sending live cane material within the country and overseas. This has now become a matter of routine and canes could now be sent almost twice round the world by steamer without seriously affecting their viability. The effect of various treatments including steeping in insecticides and fungicides on cane germination have been studied and the results have been worked into the routine of the Station. Preservation of sugarcane seeds and fluff in viable condition to carry them over from one year to another or to send them overseas has been successfully accomplished. Other such work has been on the packing and transport of seedlings as seedlings in railway wagons to various parts in the country, the effect of arrowing on juice quality, and the development of a rapid method of juice analysis for dealing with large numbers of samples during the selection period.

ECONOMIC AND OTHER RESULTS

There can be little doubt about the material benefits derived by the Indian Sugar Industry from the Coimbatore work. The facts that over seventy per cent of the cane area in the country is under the Coimbatore canes today and that there is now a fear of over-production, are positive proofs of the economic value of the Coimbatore bred canes. These somewhat quick and tangible results have been rendered possible largely because of the plan of work and the THOROUGHLY PRACTICAL methods adopted at the Station. A constant endeavour at visualizing the CROP AS A WHOLE and not in sections and keeping the studies very closely to field and CROP CONDITIONS have been the other contributory factors.

Nor have the results been less important on the purely academic side. The wide disparities that have been bridged by the inter-generic hybrids with *Saccharum* give food for thought and stimulus for further research. It may lead to a new orientation in the concept of *genus* and *species* at least in the genera and families allied to *Saccharum*. It engenders the feeling that, while perhaps a great deal has been done in plant classification, further new light may yet be in store for the patient researcher who can both describe his plants and also suitably hybridize them with one another.

(ii) Crops other than Sugarcane

(B. P. Pal, Imperial Economic Botanist)

INTRODUCTION

Since its organization in 1905, the main lines of the botanical work of the Imperial Agricultural Research Institute have been directed towards the economic improvement of Indian crops. Before the Howards commenced their classical researches on Indian crops, hardly any work had been done in economic botany in India. What little had been done consisted almost entirely of efforts to introduce exotic varieties of crops : these attempts had, however, with but few exceptions met with failure. The early work at the Institute was concerned with the amelioration of the more important crops and lay in the isolation of pure types from the mixed country crops and the selection from these types of strains which showed superiority to the existing mixed crops as cultivated by the ryot. In the beginning more emphasis was laid on a few crops like wheat and tobacco, but after 1910 many other crops were included in the programme of research, and apart from the economic improvement of these crops, fundamental contributions have been made in the study of their genetics and methods of pollination. Researches in the cytology and physiology of crop plants have also been conducted, and considerable attention has been devoted to work on the application of modern statistical principles to the lay-out and interpretation of field experiments and yield trials.

PLANT BREEDING

Probably no single branch of agricultural science has directly benefited the Indian cultivator as much as plant breeding. The improved strains of crops produced by the Institute are now well-known, and their fame has extended beyond the boundaries of India.

Some of the outstanding results achieved in this line are briefly mentioned below.

CEREALS

Wheat (*Triticum vulgare* Host).—Wheat has received much attention at Pusa because of the pre-eminent place it occupies in Indian agriculture. The value of the Pusa wheats has been recognised by the Provincial Agricultural Departments and the cultivator, and Pusa 4, Pusa 12 and Pusa 52 may now be said to be household words. In recent years other varieties have been bred by the Section, which are still further improvements on the older varieties. These new wheats not only combine high yield, good milling and baking quality, strong straw and resistance to rust, but also possess the additional advantage of being able to mature with less water than the ordinary wheats. This fact is of special significance in a country like India where lack of water is often a limiting factor in crop production.

Up to the year 1908 there was a general belief that India could produce only wheats of a relatively poor quality. An extensive series of milling and baking tests with the strains evolved at Pusa carried out by the Institute in co-operation with Dr. A. E. Humphries and Dr. E. A. Fisher, however, proved conclusively that many of the Pusa wheats possessed the character of free-milling and also yielded flour and loaves of the same class as the North American spring wheats—the wheats which are in greatest demand in England for bread making and which command the highest prices.

It is not possible in the space of a short article to describe all the Pusa wheats which are under distribution but special mention must be made of Pusa 111 which was subjected to milling and baking tests in England and proved to be equal in quality to good Manitoba wheat, and Pusa 114 which has proved such a success in Sind that in 1931-32 all the available seed of this wheat was purchased by the Sind Agricultural Department. This variety is also characterised by stiff straw and high resistance to loose smut of wheat [*Ustilago tritici* (Pers.) Jensen]. Pusa 165, a well-standing, very high-yielding, bold-grained wheat, also merits special mention. This wheat out-yielded the other Pusa and Provincial wheats in a series of trials carried out in Northern India. Another new wheat, Pusa 120, is outstandingly resistant to the physiologic races of yellow rust occurring in India. The ears and grains of some of the established Pusa wheats are illustrated in Plate II.

Recently the breeding of rust-resistant wheats has been taken up with the collaboration of Professor K. C. Mehta of Agra University. A substation at Simla, for this work, is financed by the Imperial Council of Agricultural Research.

Barley (*Hordeum vulgare* L.).—Twenty-four types of barley have been isolated and a large number of hybrids between exotic

PLATE II

and indigenous varieties are under study. Pusa Type 21 isolated in 1926 has already established a reputation for high yield, strong straw and plump well-filled grain. As a feed barley for home consumption it is ideal, but the presence of a purplish tinge on the seed-coat limits its usefulness for malting and brewing purposes, as this colour imparts an undesirable dark tint to the beer. Work has been in progress recently to breed out this colour whilst retaining the desirable characters of Type 21, and the achievement of this object is in sight.

Oats (*Avena sterilis* L. and *Avena* species).—B. S. 1 and B. S. 2 oats selected from the mixed country crop are good yielders and drought-resistant. All the indigenous oats, however, are inferior to the best European varieties in that the grain is not so plump and the straw not so abundant. In order to incorporate these qualities into the Indian oats, crosses were made between European and indigenous varieties, and a number of hybrids have been fixed which possess the good qualities of both the parental varieties. Among these may be mentioned Hybrid C and Hybrid J oats.

Breeding work with Rice (*Oryza sativa* L.) and Maize (*Zea Mays* L.) has also been in progress.

Oilseeds

Linseed (*Linum usitatissimum* L.).—Of the 124 Pusa types of this crop, Types 12, 121 and 124 have been found specially suitable for cultivation in Northern India. These types, however, have small seeds and low oil-content, compared with the types from Peninsular India which generally possess bold seeds and high oil-content. The latter, however, do not thrive in the Gangetic alluvium. With the object of combining the economically desirable characters of both classes of linseeds, Types 12, 121 and 124 were crossed with some Peninsular types, and 105 hybrids have been selected from these crosses. Out of these, Hybrids 10, 21, 55 and 68 are of value, combining, as they do, high yield and high oil-content with adaptability to grow in the Gangetic alluvium and elsewhere.

Work is in progress to produce strains of linseed immune from, or highly resistant to, rust.

Sesamum (*Sesamum orientale* L.).—Thirty types have been bred at Pusa. The best of these for general cultivation are Types 3 and 7 which are white-seeded and early, and Type 29 which is black-seeded and late. An advantage of the former is that they mature within three months after sowing, thus enabling another crop to be sown on the same land during the ensuing cold weather season. However, the white-seeded types are generally characterised by sparse branching and low yield, and attempts are being made to

hybridize a good white-seeded type (Type 3) with a black-seeded type (Type 29) with a view to combining high yield with white seed. As in the case of linseed, the trade prefers (other things being equal) a light-coloured seed as yielding oil lighter in colour than dark seed.

Work is also being carried out on *Safflower* (*Carthamus tinctorius* L.) and the oleiferous *Brassica* species.

Pulses

Pigeon-pea [*Cajanus Cajan* (L.) Millsp.].—Eighty-six pure lines of this crop have been isolated. An important cause of loss in pigeon-peas is a wilt disease caused by *Fusarium vasinfectum* Atk. which often kills off a large percentage of the plants. The Institute has been successful in selecting wilt-resistant strains of pigeon-peas, and Types 16, 41, 50, 51 and 80 possess very considerable resistance to this disease.

Gram (*Cicer arietinum* L.).—Of the eighty-four Pusa types of this important pulse, Types 17, 25 and 58 are particularly high-yielding and their seed has been in demand from many parts of India.

Improved types of *Lentils* (*Lens esculenta* Moench.), *Green Gram* (*Phaseolus aureus* Roxb.), *Black Gram* (*Phaseolus mungo* L.) and *Peas* (*Pisum sativum* L.) have also been produced and are under distribution to cultivators.

Fibres

Hibiscus (*Hibiscus cannabinus* L. and *H. sabdariffa* L.).—The "New Hibiscus" multiplied at Pusa from a single plant, the seed of which was accidentally introduced from Java, has proved a great success. It has been favourably reported upon by the Madras and Bengal Agricultural Departments. It reaches its full growth on a much smaller rainfall than is required for jute; its fibre, though not so fine as jute, compares well with it.

A hybrid between the "New Hibiscus" and another Pusa variety of *Hibiscus* has been found to surpass the former in the quality of the fibre, whilst retaining the other desirable characters of the variety.

Work on *Sunn-hemp* (*Crotalaria juncea* L.) and *Flax* (*Linum usitatissimum* L.) is also in progress.

Other Crops

Tobacco (*Nicotiana Tabacum* L. and *N. rustica* L.).—Tobacco is one of the most valuable crops grown in India and work on the improvement of the crop was commenced in 1905, attention being

paid to all the three main types of tobacco cultivated in India, *i.e.*, cigarette, chewing and *hookah* tobaccos. Sixty-nine types of *N. Tabacum* and twenty types of *N. rustica* have been isolated, of which Types 28 and 63 (chewing tobaccos) among the former, and Type 18 (*hookah* tobacco) among the latter, are under distribution.

The leaf produced in India is generally of a coarse heavy type with a dark colour and a strong flavour. This type is suitable for the local market and a large amount is also exported, mainly to Great Britain, where it is used principally for mixing with other leaf in the preparation of pipe tobaccos. In recent years, however, the principal feature of the leaf tobacco trade of the world has been the large and still increasing demand for the cigarette type of tobacco. As none of the indigenous tobacco varieties was found to be suitable for cigarette production, hybridization between exotic and indigenous varieties was resorted to. From the crosses which were made, two strains, H 142 and H 177, have been selected as being very suitable for cigarette manufacture. These combine the fine leaf quality of the foreign tobaccos with the greater hardiness and yield of the indigenous varieties. The Institute has played an important part in the development of a technique of flue-curing of tobacco suitable for Indian conditions, and the rapid development of the cigarette tobacco industry in the Guntur District of the Madras Presidency has been made possible by the researches conducted at Pusa.

A special short course in the flue-curing of tobacco conducted every year by the Institute since 1933 has proved popular and has been attended by officers from Provincial and States Departments of Agriculture.

Potato (*Solanum tuberosum* L.).—The breeding of potatoes suitable for Indian conditions and possessing also resistance to late-blight and virus diseases is in progress. The work is being facilitated by the provision of a substation at Simla, financed by the Imperial Council of Agricultural Research.

Chilli (*Capsicum annuum* L. and *C. frutescens* L.).—Fifty-three types have been isolated, of which Types 34, 41, 46 and 51 are being distributed.

Work has also been done on the improvement of *Hemp* (*Cannabis sativa* L.).

PLANT GENETICS

The Institute has paid considerable attention to the genetical study of Indian crop plants. The genic analysis of the existing strains of crop plants is not only of scientific importance but of practical value as well, as such knowledge facilitates the selection

of varieties for use as parents in plant-breeding work. A brief summary of the genetical work done on each crop is presented below :—

Wheat.—One of the earliest studies conducted in India on Mendelian inheritance was the study of a number of characters, *viz.*, felting of chaff, colour of grain, colour of chaff, presence or absence of awns, etc., in wheat. Felting of chaff was found to behave as a monogenic character in certain crosses and as a digenic character in others, the presence of felt being dominant to its absence. Red colour of grain was dominant to white or yellow colour, depending for its expression on one, two or three independently inherited factors. Red chaff behaved as an incomplete dominant to white chaff in F_1, giving the usual 1 : 2 : 1 ratio in F_2. The awning of wheats was demonstrated to depend upon two factors, giving a " tipped " F_1, and a ratio of 15 awned (various grades) : 1 awnless, in F_2.

Barley.—The inheritance of fertility of lateral florets—an important criterion in barley classification—was found to depend on a single factor difference in one cross, and on more than one factor in other crosses.

Hooded condition was dominant to the awned, giving in F_2 a ratio of 3 hooded plants : 1 awned, but the occurrence of various grades of hoodedness indicated that this character is determined by more than one factor. Hulled grain proved dominant to naked grain in both varietal and interspecific crosses. Purple colour in pericarp and aleurone layer was found to be determined by a single factor in each case while purple colour in the glume was controlled by two factors.

An examination of the internal stem structure of the F_2 plants of a cross between a lodging and a non-lodging barley showed that the development of the mechanical tissue is also controlled by Mendelian factors, two factors being concerned in this case. In the non-lodging type, the sclerenchymatous tissue was thick and well-developed, and regular sub-epidermal " girders " were present which helped to strengthen the culm ; in the lodging type, on the other hand, the sclerenchyma was poorly developed and hardly any sub-epidermal " girders " were present.

The branching of ears in barley was shown to be recessive to the unbranched condition, and to depend upon the interaction of two factors.

Oats.—Interspecific crosses between *Avena sativa* and *A. sterilis* var. *culta* have been studied. Single factor differences have been noted between " strong " and " weak " awns, and between long

and short basal hairs. Two factors were found to control basal hairs of leaf-margins.

Height of plant, number of days taken to head out, and number of spikelets per panicle were demonstrated to be dependent upon multiple factors.

Linseed.—Linseed has been the subject of a complete genetical analysis in an investigation which had primarily an economic object. The colour of petal was shown to be determined by the action and interaction of seven factors some of which also influence the colour of the other floral organs and of the seeds, so that it is possible to predict the colour of the seed from that of the petal. This is important because correlation studies have demonstrated that light-coloured seeds have a higher oil-content than dark-coloured seeds. Investigations have further indicated that the factor which converts yellow seed colour to gray, and fawn to brown, is also responsible for lowering the oil-content. This finding, when confirmed, should prove of practical value in simplifying and quickening the process of breeding for high oil-content in linseed.

Work is also in progress with the object of breeding a recessive genotype in which all the known factors for petal colour and also some of the seed colour factors are absent. Such a genotype would be useful as a " tester " for genetically analysing new varieties.

Safflower.—Genetic work on this crop was taken up comparatively recently, and the mode of inheritance of flower colour, spininess of leaves and bracts, shape of bracts, etc., is under investigation.

Sesamum.—Light purple colour of the lower lobe of the flower was found to be dominant to purple colour. Erect habit, three flowers per axil, and white seed behaved as simple recessives to bushy habit, one flower in the axil, and black seed, respectively.

Pigeon-pea.—The mode of inheritance of a number of characters, including resistance to wilt, has been studied in this crop.

It was found that the erect habit of plant was partially dominant to spreading habit on a monogenic basis. Short stature of plant and crowded habit of inflorescence were dominant to tall stature and open habit, respectively, on a 3 : 1 ratio. Flower colour depended upon the interaction of two factors. Brown seed colour was dominant to silvery white on a 3 : 1 ratio, although it was suspected that the mode of inheritance may be really more complex.

Wilt resistance was found to be dominant to wilt susceptibility on a 9 : 7 or 27 : 37 ratio, and segregated independently of the morphological characters studied.

Gram.—The inheritance of flower colour in gram has been studied, and it has been shown that it depends upon the interaction of several factors. Blue colour is produced by a factor **P** in the presence of **B** ; in the absence of **B** the flower is white whether **P** be present or not. Greenness in the standard is developed in the absence of an inhibitory factor **W**. Single pedical has been found to depend upon a factor **S** and is dominant to double pedical. The inheritance of seed colour and shape has also been studied. Investigations are in progress on the selfed and crossed progenies of two interesting mutants.

Hibiscus.—Colour of stem, petiole, corolla, calyx, nature of leaf-lobe, hairiness of stem, etc., are some of the characters of which the mode of inheritance has been worked out. The different colours on the stem, leaf-veins, and calyx were found to depend upon one, two, or more factors. Red colour in stem, whatever the kind, was associated invariably with that in the eye of the corolla and the capsule, but its expression depended upon yet another factor.

Narrow leaf-lobe and yellow corolla were dominant monogenically to broad leaf-lobe and white corolla. Hairiness of the stem behaved as a digenic character, giving a ratio of 15 hairy (various grades) : 1 non-hairy.

Tobacco.—The inheritance of a number of qualitative and quantitative characters, *e.g.*, height of plant, time of flowering, number of leaves per plant, leaf-shape, leaf-margin, size and colour of corolla, has been the subject of intensive study since the early days of the Institute.

In all the quantitative characters studied the F_1 was intermediate between the parents, and in the F_2 the range of variation was as great as that of both parent varieties combined. The number of leaves per plant was independent of the plant height and distinct segregation was observed in respect of the arrangement of leaves on the stem. Venation of leaves proved to be one of the most constant characters of the plant. Frilled leaf-margin was dominant to smooth on a monohybrid ratio.

A cross between *N. Tabacum* L. and *N. plumbaginifolia* Viv. was successfully made and the hybrids raised to maturity. Previous investigators had either failed to make the cross or obtained only a few weak seedlings which died after producing 4-5 leaves. The hybrid was more or less intermediate between the two parents but showed a number of new characters such as streaking and striping of flowers, presence of accessory corolla lobes, and complete sterility. In nicotine content it was again more or less intermediate, though nearer the parent with the higher nicotine content.

Chilli.—The inheritance of a large number of characters has been studied in this crop which has been found to be very suitable material for demonstrating the laws of inheritance to students.

CYTOLOGY

Apart from their scientific interest, cytological studies help in the tracing of relationships between different species and varieties of a crop and also explain why certain species and varieties cross more readily than others or sometimes fail altogether to cross. In the absence of a cytologist on the staff, the work on this line has necessarily been limited.

Chilli.—Cytological study of this crop plant showed that the diploid chromosome number is 24.

Gram.—Attempts to cross the white, large-seed *kabuli* gram with the red or brown *desi* gram often met with failure, and when successful, the interpretation of the genetic results proved difficult. Cytological investigations however showed that while the *desi* gram has only $2n=14$ chromosomes, the *kabuli* gram has $2n=16$.

A gigantic mutant from Type 22 gram was found to possess 16 chromosomes as compared to 14 in the variety from which it originated.

PHYSIOLOGY

A few of the more important investigations on this subject are mentioned below.

The cause of the wilting of Java indigo which takes place after the first cut in July was investigated and found to be due to the loss of the active root-system of the plant, resulting from a long-continued wet condition of the soil.

A good deal of work has been done on the importance of drainage and soil aeration in the production of crops, and it has been shown that these two factors may influence crop production perhaps even more than manuring.

The response of sesamum to different soil conditions has been studied in pot culture, the results indicating that this crop requires a light soil, with an adequate amount of moisture, for its maximum growth.

The influence of manures on the wilt disease of pigeon-pea has been the subject of a collaborate study and important results have been obtained. It was found that superphosphate and cattle manure increased the incidence of wilt disease, while green manure (*Crotalaria juncea*) showed a definite tendency to decrease it. Superphosphate and green manure together increased the incidence of wilt. In newly-infected land the wilt spread rapidly.

Neither the moisture nor the hydrogen ion concentration were the controlling factors of wilt in the experiments conducted in the Pusa soil. Superphosphate was observed to increase the root development and the weight of the aerial shoot, and its increasing concentration also promoted the growth of the fungus up to a certain point after which further concentration checked growth.

Work on the effect of a tobacco crop on the wilt disease of the succeeding pigeon-pea crop is in progress. The preliminary observations indicate that the tobacco has a beneficial effect in checking wilt in the crop of pigeon-pea which follows it.

The effect of fertilizers on the growth and oil-content of linseed has also been investigated, the investigation showing that sodium nitrate and complete fertilizer caused an increase in height of plant, number of basal branches per plant and yield of seed per plant. Potassium sulphate had no effect on the yield of seed and superphosphate caused reduction in yield but induced early flowering. Oil-content was not significantly increased or decreased by any of the fertilizers applied. The addition of 30 per cent organic matter in the form of leaf-mould produced an increase of about 30 per cent in height, 100 per cent in the number of basal branches and 250 per cent in the yield of seed.

An interesting investigation on the influence of artificial stimuli such as removal of flowers, injecting chemicals, mutilation of various parts, etc., on the sex ratio in *Cannabis sativa* has been conducted, and the results showed that these had no appreciable effect on the sex ratio in the variety experimented upon. There was also no noteworthy difference between the sex-ratios observed in the progenies of plants pollinated with fresh and old pollen.

MISCELLANEOUS

Classification.—Most of the important Indian crops have been classified after thorough studies of varieties received from all parts of India. It is perhaps unnecessary to point out that such work is necessary as a first step in the improvement of varieties, as it clears the ground and gives the plant breeder a supply of raw material upon which to work. Collections of crop types are regularly maintained by the Institute.

Root studies.—A study of the root-systems in fifty different strains of chillies has shown that the extremely vigorous fibrous type of root-system is associated with vigorous shoot-growth and with productivity. In barley, an examination of the roots of thirty different types disclosed that there were four main types of root-system which may be termed mesophytic, semi-mesophytic, semi-xerophytic and xerophytic. Shallow-rooted barleys were characteristically earlier in maturity than deep-rooted ones.

In green gram and black gram, two distinct types of root-system were discovered : the mesophytic type adapted for drawing its water supply from the upper layers of the soil, and the xerophytic adapted for tapping water from deeper layers.

Sterility studies.—Investigations on this important subject have been carried out with a number of crops. In the species of *Brassica* investigated the pollen was found to be not defective. In *Eruca sativa* Mill. it was observed that sterility may ensue owing to the female reproductive organs being defective. It was shown that in compatible unions the pollen reached the ovary in a shorter time than in compatible matings, the sterility in the latter being due to the failure of the pollen tube to reach the ovule before it lost its receptivity.

The cause of the shedding of flowers and poor capsule formation in a variety of tobacco during the period December-January at Pusa was studied. The data obtained indicated that the pollen of this variety was probably unable to function at the low temperatures prevailing at that time of the year.

The poor bearing in certain late varieties of plum was investigated, and it was found that the stamens of these varieties were defective and did not form pollen at all ; owing to the difference in the time of flowering, the flowers of the late varieties could not be pollinated by the fertile pollen from the early variety.

Fruit investigations.—A considerable amount of work on a large number of fruits has been done by the Institute, both at Pusa and at the Fruit Station at Quetta. It is, however, not possible to describe this here. The fruit work was discontinued later owing to lack of specially trained staff. It is hoped that it may be possible to re-commence this important line of work in the future.

Virus disease studies.—The leaf-curl disease of tobacco is under study. Five types of leaf-curl have been tentatively distinguished.

The " green flower disease " (phyllody) of sesamum, formerly believed to be due to physiological causes, has been shown to be probably of virus nature.

Studies of resistance to insect pests.—The relation between the internal stem structure of certain varieties of gram and their resistance to cutworm attack was investigated, the results indicating that the severity of cutworm attack is directly associated with the internal structure and thickness of the stem, the caterpillars causing most damage to those varieties which typically possess slender, soft-wooded stems and hence offer less resistance to the insects' jaws. The demonstration of such a simple direct relation between the anatomical characters of varieties and their liability

to insect attack is not only of interest but suggests as a practicable measure for the control of the cutworm the selection of tough-stemmed varieties for cultivation in tracts particularly liable to the ravages of the pest.

Field Experimentation and Yield Trials.—An outstanding feature of the work of the Institute in recent years has been the application of modern statistical principles to the lay-out and interpretation of field experiments and yield trials which is of paramount importance in any agricultural research work. The "Handbook of Statistics for use in Plant Breeding and Agricultural Problems" written by the late Dr. F. J. F. Shaw as a result of experience gathered in teaching post-graduate students and recently published, should prove of value to students in Indian Universities and Agricultural Colleges and to workers in Agricultural Departments.

Miscellaneous.—Several other problems have been the subject of investigation, *e.g.*, the effect of vernalization on wheat, barley and oats, etc., but it is not possible to give an account of them in a brief summary.

(*c*) SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

(B. Viswa Nath, Imperial Agricultural Chemist)

INTRODUCTION

Research in soil science and agricultural chemistry began in India with the establishment of the Imperial Agricultural Research Institute at Pusa in the year 1905. Substantial preliminary work had already been done by Dr. J. W. Leather, who was appointed Agricultural Chemist to the Government of India a few years previously. Being then the only Agricultural Chemist in the country, he toured extensively and collected considerable data on the composition of Indian soils, manures, food and industrial crops, river and well waters. These were published from time to time in the series of publications known as Agricultural Ledgers. He had then also the facilities of the experimental farms at Cawnpore in northern India and at Saidapet in southern India.

When Dr. Leather commenced work at the Institute, he had the unique advantage of an intimate knowledge of the diversity of conditions and an appreciation of the position after the classification and interpretation of the data accumulated by him. This enabled him to anticipate modern developments. In his soil surveys he had examined soil sections and depth distribution of soil layers, salts and moisture. The earliest example of such a study

is that of black soils reported in the early reports of the agricultural experiment station at Hagari, in Madras. He recognised, even in those days, the difficulties in sampling soils, and discussed errors involved in field and laboratory work. Error determinations of soil moisture in analyses of soils, sugarcanes and milk were among the earliest published investigations, and all his subsequent work is characterised by the constant appreciation of the effect of personal and chance errors in experiments. He had also recognised the necessity for standard and agreed methods in agricultural analysis. As work in the provinces developed, he issued, in consultation with his colleagues in the provinces, a bulletin of official and recommended methods of analysis. When subsequent experience indicated revision of the methods, referees were appointed and suitable alterations were made at conferences of agricultural chemists and bacteriologists.

Till very recently research and investigation in agricultural chemistry at the Institute included animal nutrition and dairying. The scope of enquiry thus covered a wide field and dealt with various questions concerned with soils, fertilisers, crops, foods and fodders, animal nutrition and dairy chemistry. The names of Dr. Leather for pioneer work on soils, and plant and dairy chemistry, of Mr. C. M. Hutchinson for work in soil biology and of Dr. F. J. Warth for work in animal nutrition will be long remembered. Their work yielded information of the greatest value on many of the fundamental factors which must always influence the science and practice of Indian agriculture.

The range of subject matter being extensive, a review of this nature must necessarily limit itself to a few of the major features of long years of research and investigation, the results of which have either influenced or are likely to influence agricultural science and practice in the country, and exclude a good deal of work of potential value.

SOILS—PHYSICAL AND CHEMICAL

General soil survey.—Three decades ago, the terms "*pedology*" and "*soil science*" were not known. Views on soil as the medium for plant growth were very much under the influence of Liebig's mineral theory of plant nutrition. Scientific agriculture meant agricultural chemistry. It was considered that a simple chemical analysis was enough to assess soil fertility, and that it could be maintained by making good the deficiencies revealed by such analysis. Soil work began, therefore, with surveys to classify soils in terms of sufficiency or deficiency of the major fertiliser constituents.

The surveys distinguished four major types of soils :—(1) The Indo-gangetic alluvium, (2) the black or regur soils, (3) red soils lying on metamorphic rocks, and (4) laterite soils. In addition, stretches of alluvium along the east coast at the mouths of the great rivers have been noted to occur. Soils from the plains have been shown to contain much less organic matter and nitrogen than European soils, and to be generally deficient in other constituents also, particularly in phosphates, and to a lesser extent in sulphate and lime, compared to the composition of European soils.

In regard to their genesis the soils of India offer a distinct contrast to those of Great Britain. The soils of the plains being very old and fully mature do not exhibit the close relationship to the rocky substratum found in the young and immature soils of Great Britain. Processes leading to differentiation of soils into horizons are influenced chiefly by the relative intensities of rainfall, evaporation and temperature. The oxalate solubility of trivalent cations associated with soil colloids indicates ageing of colloids.

Soil temperatures.—The temperature of the atmosphere in and outside the soil exercises considerable influence on the soil chemically and physically and more especially on the biological processes in higher plants and lower organisms. The temperature of the soil depends on its capacity to absorb radiant energy, specific heat, heat conductivity and night radiation, which vary with the nature of the soil, its moisture content and the presence or absence of vegetation on it.

Alluvial and black soils have very different heat conductivities, and variations in diurnal temperature in black soils are larger than in alluvial soils. In the alluvial soil at Cawnpore it was observed that the difference in the diurnal maximum and minimum at the surface in the month of May was 16 degrees (50°C. Max.—34° C. Min.), while at a depth of 2 feet the difference between the maximum and minimum temperatures was only one degree (36°C.—35°C.). In the case of the black soil at Nagpore the difference was 23 degrees (54°C.—31°C.), while two feet below it was 10 degrees (44°C.—34°C.).

At Pusa, records of soil temperatures were maintained for several years in soil, with and without crop, at several depths between one inch and 24 inches from the surface. As is to be expected, the temperature varies with the hour of the day and with the season. The minimum occurs in January and the maximum in the month of May.

In bare fallow soil, the diurnal variation extends to between 12 inches and 24 inches below the surface on most days in the year.

The diurnal variation is least during monsoon and greatest during dry season. A change in the specific heat of the soil, due to change of moisture content, does not seem to affect the maxima or minima, but rainfall during the dry season followed by a considerable change in evaporation has a marked effect.

The effect of crop on the soil temperature is naturally very marked. The diurnal change at one inch depth is about 13°C. for cropped soil as against 20°C. for exposed soil. While the temperature at the surface of the bare fallow soil rises to about 20°C. above that of the air, the corresponding figure for cropped land is about 3°C. even in March and in the rains it is actually lower than that of the air.

Soil gases.—Studies on gaseous exchange in soils have shown that diffusion of gases is so rapid as to prevent a deficiency of oxygen and that soil cultivation at the surface does not contribute to better aeration. A sampling tool and an attachment devised for pumping gases from the undisturbed soil, enabled the collection of gases at specified depths from blocks of soil, at the same time eliminating contamination with outside air. Direct measurements were made in Pusa soil of the volume of gases and water at different depths, in different seasons and of the proportions of gases dissolved in soil water in cultivated and fallow land, manured land, swamp land and in fallow land before and after nitrification. In the neighbourhood of plants the gases contained a high proportion of carbon dioxide, a low proportion of oxygen and some hydrogen. Treatment with manures and the proximity of the roots of plants have been found to modify the composition of the gases. From estimations of argon it has been demonstrated that the nitrogen of the gases in swampy soils is mostly derived from the soil and manure.

Soil texture.—The determination of the state of sub-division of the soil is of importance in the study of soil problems relating to irrigation, moisture capacity and plant growth. The size and nature of the particles composing the soil determine the texture and the physical properties of the soil, and the information in this regard is obtained by a mechanical analysis, which depends on the depth distribution of the particles in a settling suspension of soil and water. A simple method of dispersion by leaching the soil with dilute sodium chloride has been evolved. This method has all the advantages of preliminary acid treatment, as enjoined by the International method, as regards its reproducibility, and is free from objections as to loss of soil constituents like calcium carbonate when the soil is treated with acid.

Combining the results by this method and those by the method without pre-treatment, a value is obtained by which it is possible

to assess the field texture of the soil and the extent to which further sub-division will take place under adverse conditions like water-logging and alkalinity.

Soil reaction.—The theory and methods employed for the measurement of hydrogen ion concentration as developed by Sörensen and by Clark and applied to soil by Gillespie, have enabled us to express the reaction of a soil in terms of pH scale. The methods developed are, however, unsuitable for general application over wide areas and to a wide variety of soils. Besides they require complicated, expensive and delicate equipment, which cannot be carried about in the field, in soil survey work. Another difficulty is that different values are obtained for the same soil depending on the method adopted in the preparation of the sample. It has been observed that the closer the conditions approximate to that of the soil *in situ* the more concordant are the results obtained. On investigating several metallic electrodes such as those of tungsten, molybdenum and antimony it has been found that a rod of pure antimony dipped into moist soil develops an electric potential closely agreeing with the values by hydrogen electrode. A portable apparatus has been designed for employment in the field.

Profile studies.—Soil profile does not have the same significance in India as elsewhere and in most cases the surface horizons are missing due to age and erosion through centuries. As early as 1906, Leather examined profiles of several black soils and alkaline soils. In recent years studies of profiles of soils with reference to changes in the composition of different soil layers, with manurial treatment and crop growth, have shown characteristic variations in the chemical composition of the different layers. A study of the alkali soil profile in the Kalar area in Sind indicates the operation of two processes : (1) accumulation on the surface horizon of salts of alkali metals and (2) base exchange, replacing the calcium of the complex by sodium and the washing down of the calcium into lower layers. Similar processes appear to have occurred in the soils of Delhi, the difference being that in Sind soils gypsum has accumulated while in Delhi soils calcium carbonate stratum has formed. Monovalent ions tend to remain at the surface while bivalent ions move downward. Of the trivalent ions, *e.g.*, iron appears to be hardly affected but aluminium moves down in solution.

Soil water.—In a country like India where the amount and distribution of the monsoon rainfall mean so much to the agriculturist, the study of soil and water relationship are of particular importance. The determination of the quantity of rain water, which descends into the surface soil, how much of this passes into the sub-soil drainage, and how much of it evaporates again into

the atmosphere is a subject, which has received considerable attention. Early in the history of the Institute, drain gauges were erected and continuous observations have been made for three decades to obtain information on (1) the amount of water which percolates per unit of time and its relation to rainfall, (2) the amount of water which flows off a level surface, (3) the proportion of rainfall which evaporates, (4) the effect of growing crops on these proportions and (5) the plant nutrients that pass away in the drainage water. It has been found that the loss of rain water from soil is fairly constant year by year. If conditions are satisfactory, half of the rainfall can percolate into the soil. Surface drainage or run-off varies with the nature of the soil and its permeability and when properly cultivated this loss is comparatively little except under cloud bursts. Evaporation varies from 14 to 20 inches per annum and the effect of crop is to reduce the evaporation to two-thirds or half of what it would be on bare fallow soil.

The evaporation from the surface of a sheet of water was studied at Pusa in a specially constructed evaporimeter. With the aid of suitable formulae the amount of water lost by evaporation has been calculated. For Pusa it was 100 cm. (40 inches), for Madras it was 175 cm. (70 inches) and for Lyallpur it amounted to 185 cm. (74 inches).

Loss of nitrates through drainage in Pusa soils varied from 30 to 50 pounds nitrogen to the acre and more. It is considerable in fallow cultivated land. The presence of crop reduces this loss, which is least when the soil is under permanent grass. A further loss occurs during the hot season through the lowering of water table taking the solution of nitrates into the deeper layers.

Soil moisture.—In regard to the fate of moisture retained by the soil, Leather (1908) was among the first to draw attention to the inadequacy of the hypothesis of capillary lift of water from deeper layers of soils. He has shown that during dry period water moves upwards in the soil from a very limited depth only. At Pusa it was about 3 feet, and below this the moisture content was stationary.

The loss of water from soil has been shown to follow the compound interest law. Loss is greatest immediately after rain and temperature considerably influences this because of marked change in viscocity.

The phenomenon of absorption of moisture by soils has been studied. The absorption is determined mainly by the content of clay and its character. With a 25 per cent solution of glycerine in water soils absorb quantities of moisture which are exponential functions of the clay content. Temperature is an important factor

in regulating the extent of moisture absorption, which falls by nearly fifty per cent as the temperature of the soil increases. A soil possessing 2,000 sq. cm. of surface per 1 c. cm. of soil will absorb or lose water more rapidly than one possessing 4,000 to 6,000 sq. cm. of surface.

These conclusions have for Indian soils a value beyond the mere knowledge of the rate of movement of moisture. They show that soluble salts cannot move during dry weather more than a very limited distance and limit our assumptions about alkali and distribution of plant food, and throw light on problems of irrigation and salt accumulation.

It is considered that crop plants absorb both the water and dissolved salts and that therefore the ideal irrigation system is to apply only enough to keep the root zone sufficiently wet. But it has been found that crop plants do not absorb salts in the same proportion in which they are contained in irrigation water, and that only water is absorbed in much larger proportions, leaving a larger percentage of salts in the soil. Irrigation water used in highly saline soils requires to be regulated in relation to crop growth to avoid salts reaching the root range, and it is necessary to give copious irrigations when there is no crop to wash down salts.

Water requirements of crops.—An important corollary to the investigations on soil-water relationship is the investigation on the water requirements of crops, a subject to which the Irrigation Commission drew pointed attention (1903). The subject was investigated in great detail first at Cawnpore and later at Pusa. The amount of water transpired by crop, the period of growth during which greater part is assimilated, ratio between water transpired and dry matter produced, were studied having regard to the effects of temperature, humidity, proportion of soil and manure, both in pot cultures and on the field scale. Several cold and hot weather crops were experimented with. The whole of the experimental evidence indicates that if the quantity of water, which can move through a soil per unit time, were dependent on the factors—concentration, distance and the physical character of the soil and temperature, the water requirements of crops could be accounted for by the estimation of the soils' capacity for delivery of water to the plant.

The nature of soil appears to have no effect on the transpiration ratio, provided water supply does not fall below a minimum concentration, but profoundly influences the rate at which water can move through the soil and hence the total crop produced. The mass of soil has an influence. The smaller the mass the higher is the ratio.

The concentration of moisture necessary for good development of plants varies largely with the nature of the soil. In Pusa soil, 10 per cent of moisture was sufficient for the development of normal plant, while in black soil 25 per cent is too small for anything but the most meagre growth.

In the field, the action of the plant is to cause a marked decrease in moisture concentration throughout a specific depth of soil. This reduction in concentration of moisture is more or less uniform in Pusa soil to a depth of about five feet, below which the change is smaller.

The addition of superphosphate resulted in a smaller transpiration ratio, but this did not appear to be due to any specific action on the soil moisture system, but to the better and more complete plant development.

Soil colloids.—Most of the physico-chemical properties of the soil are chiefly due to the reactions brought about by the clay fraction, which is colloidal in character. The composition of the colloids in different soils may differ, but there are certain properties common to all soil colloids. Base exchange and soil acidity, the factors that influence the dispersion and flocculation of soil colloids in water, the methods of estimating the colloids and the methods of determining saturation capacity and the degree of saturation of soils, were investigated.

Studies on reactions in soils which are completely unsaturated with respect to their bases, by treatment with dilute acids, have shown that in mineral soils especially, acidoids show reactions similar to those of soluble acids. The reactions take place in three stages, in which one, two or three equivalents of hydrogen can take part. These investigations show that in so far as the physico-chemical properties of soil colloids are concerned, there is no distinction between acidoids and true acids and saloids and true salts.

New methods for estimating base exchange capacity by removing exchangeable bases from soil colloids by electro-filtration and electro-dialysis have been evolved, and it has been found that, for a given soil, the base exchange value is a constant and may be used as a characteristic. Methods of determining saturation capacity and the degree of saturation of soil colloids have been critically examined and new methods of estimating the state of saturation evolved.

Factors influencing the dispersion and flocculation of soil colloids have been investigated with reference to the nature of the exchangeable ion. The nature of the replaceable base in a soil has been shown to have a profound influence on these properties.

The whole of the hydrogen in a fully unsaturated soil has been shown to be merely surface active, and none of it appears in solution unless brought in contact with a neutral salt. The next step was to investigate the toxicity of the surface active hydrogen to autotrophic bacteria and plants. Ammonifying, nitrifying and nitrogen-fixing organisms did not thrive in a fully unsaturated soil, but resumed normal growth on neutralising the first moiety of surface active hydrogen. Exchangeable sodium has no direct toxic effect on plants, but the indirect effect is considerable owing to the influence of sodium ion on the permeability of the soil.

Saline and alkaline soils.—The problem of alkaline and saline soils was recognised as early as 1894 and extensive surveys were made of alluvial lands of Delhi, Unao, Lucknow, the Punjab, North-West Frontier Province and the black soils under Nira Valley Canal and Kaira. Intensive studies were carried out on the alkali soil profiles in the Mainpuri District and the fact was established that the upward movement of water and salts was nominal, but that large lateral variations occurred. The composition of well waters and the composition of canal and river silts as sources of fertiliser and deleterious salts were also investigated. Legumes, peas and gram appear to be more affected by *usar* salts than plants of the Gramineae family, and on the more open soils sodium chloride is more harmful than sodium carbonate.

Studies on the incidence and amelioration of alkaline soils necessitate a distinction between alkaline and saline soils. A soil under irrigation is not a simple existence of the two components, water and inert solid matter, lying side by side. The two components undergo a series of interactions brought about by frequent irrigations and intensive cropping. If either the soil or water or both happen to contain sodium salts in excess of calcium salts, the composition of the clay complex is altered into that of sodium clay and the soil becomes impervious to water. If the soil is rich in calcium salts or the irrigation water contains a greater proportion of calcium salts, no marked change in the composition of the clay complex occurs. In such soils percolation will be rapid and very soon the soil is left with an amount of water equivalent to its saturation capacity. The phase that follows is one of decreased evaporation and diminished percolation both going on at a steadily diminishing rate until the water content of the soil is reduced to the neighbourhood of minimum capillary capacity. Under such alternating conditions with excess and deficit moisture, the soil reaction swings between alkalinity and salinity. When the soil is too wet alkalinity will be more in evidence and salinity is diminished, owing to dilution and hydrolysis. When the moisture concentration becomes low alkalinity is diminished, but salinity may attain injurious concentrations.

Acid soils.—Soil acidity, in the mineral soils especially, has been shown to be due to insoluble colloidal acids probably of the complex alumino-silicate type. In regard to the quantitative side of soil acidity, it has been shown that the addition of lime does not bring about immediately a steady pH value of the soil, but takes a fairly long time interval before attaining equilibrium and that a much larger quantity of lime than that required to bring the pH to 7 should be added under field conditions to permit normal crop growth.

Soil solution with solid, liquid and gas phases in soils.—The water present in the soil is in a state of solution with varying solubility relations in the several systems containing calcium carbonate, carbonic acid gas and/or magnesium carbonate and water. It is of practical importance to ascertain how much of these salts can be in solution in the soil water under varied conditions. Data were first obtained respecting the system, water—calcium carbonate—carbon dioxide, at temperatures from 20°—40°C. and for a partial pressure of carbon dioxide in the gas phase, which varied from 0—35 per cent. Later, the studies were extended to systems containing magnesium carbonate. The latter dissolves in the presence of water and carbonic acid as a bicarbonate, which is very much more stable than the corresponding calcium salt and is about ten times more soluble. When the two bicarbonates are present together it is to be expected, from a consideration of the law of mass action, that calcium carbonate must become more or less precipitated from solution in the presence of relatively more magnesium carbonate. No fertile soil can, therefore, contain much magnesium carbonate, for in that case the calcium carbonate would become so far insoluble as to cause ' lime hunger ' and consequent infertility. Generally, the magnesium of soils, which is not present as silicate or dolomite, will be combined with other acid radicals. These investigations were a step towards a more exact knowledge regarding the concentration of lime in the aqueous solution of the soil. Although impossible to obtain this solution from the soil in an unaltered state, it is feasible to obtain specimens of the gases and, from a knowledge of their composition, to make deductions regarding the amount of carbonic acid gas in solution and hence also regarding the concentration of calcium and other carbonates.

This work has also placed in our hands a general formula for the investigation of other systems. It has been possible to apply it to the study of the soluble phosphates in the presence of calcium carbonate and carbon dioxide. The solubility of soil and rock minerals has been repeatedly shown to be much greater in the presence of carbon dioxide than in pure water, and accordingly this constituent has been considered an important natural solvent of plant

food in the soil. But, when water, calcium carbonate and carbon dioxide are put in such proportions as occur naturally, there is no increase in phosphate solubility. Indeed, the effect generally is reduced solubility.

Availability of phosphate and potash in soils.—Numerous laboratory analyses, pot cultures and direct field experiments in different parts of India, have established general phosphate deficiency, and response to phosphate treatment. In these investigations it has been found that Dyer's method of estimating available phosphate by extraction with dilute citric acid is inapplicable to calcareous soils. Extraction with dilute solutions of potassium carbonate yielded results, which could be better correlated with crop yields than the results by the citric acid method. Investigations on the mechanism of retention of phosphate in soils have shown that in calcareous soils retention is due to chemical combination, but if the phosphates are neutral or alkaline it would be absorption instead of chemical combination. Alkaline phosphates would, therefore, be more suitable than super in calcareous soils. Meta- and pyro-phosphates of sodium do not interact with calcium carbonate at ordinary temperature, while di-sodium hydrogen phosphate reacts with calcium carbonate precipitating the phosphate.

Investigations on phosphate and potash availability in soils by biological methods employing micro-organisms and seedling plants were carried out. Their applicability in determining fertiliser requirements is problematical.

SOILS—MICROBIOLOGY

At the time when the Bacteriological Section of the Institute commenced work, very little was known of the relation of microbiological agencies to soil fertility in India. In those days, even outside India, soil microbiological processes were still under study, and many fundamental theories connecting bacterial action with soil fertility were not yet accepted as axiomatic. Three decades of research and investigation have enabled us to understand more clearly the part played by micro-organisms in soil fertility and the means by which their activities can be controlled.

Biological survey of soils.—Early work was concerned principally with biological surveys of soils, the study of soil organisms and their behaviour under different conditions of soil and environment. The general characteristics and behaviour of the micro-organisms in Indian soils have been found to be, in the main, similar to those observed in European soils. There are instances in which variations due to environment have been observed in the nature and reactions of various organisms. For instance, cultures of *Azotobacter* from different soils have been found to vary in their morphological and

cultural characteristics and also in their capacity for fixing nitrogen.

Biological oxidation in soils.—Another line of enquiry in the early years was in the direction of ascertaining the factors that determine biological oxidation in soils and in measuring the changes resulting therefrom under various conditions. Particular attention was paid to the supply of available nitrogen as provided by the biolysis of such substances as green manures, crop residues and organic manures. High temperatures that usually obtain in Indian soils have been found to accelerate carbon oxidation, ammonification and nitrification at a rate many times faster than in soils of temperate climates. Between 15°C.—18°C. ammonification precedes nitrification at such a rate as to allow the latter to proceed *pari passu*; at 25°C.—30°C., however, ammonification proceeds with such rapidity that some ammonia escapes oxidation and is lost. The retardation or inhibition of the process of nitrification in the presence of large quantities of organic and ammoniacal nitrogen has been traced to the insufficiency of nitrate-forming organisms to deal with these concentrations.

Sunlight and ultraviolet light have been found to have no effect on the oxidation of ammoniacal nitrogen. On the other hand the nitrates in the soil are decomposed.

Longevity of micro-organisms in soils.—Comparative studies on soils collected and stored in 1906 and of soil samples collected from the same plots in 1935, have given interesting information on the longevity of micro-organisms in soils on storage. The numbers of organisms in the older soils are 16-50 per cent less than in the recent ones, depending on the medium employed. Storage for thirty years has not affected spore-forming organisms, and the activity of urea-splitting and ammonifying organisms has not diminished. The capacity to oxidise carbon by organisms is there, but nitrifying organisms appear to have disappeared. There is also no evidence of nitrogen-fixing organisms and no colonies of *Azotobacter* appeared.

Symbiotic bacterial decomposition of cellulose.—In the course of studies of enrichment cultures for cellulose decomposition, an organism which will decompose cellulose only when grown in association with certain other organisms occurring in cattle dung or soil has been isolated. The ratio of the amount of nitrogen used to the amount of cellulose decomposed has been found to be 1: 40 with one of the symbiotic organisms and 1: 50 with another. Alcohol, acetic acid and butyric acid are among the decomposition products. No reducing sugars are found to be present when starch is decomposed, but alcohol, aldehyde and formic, acetic and butyric acids are found in the products of decomposition. When grown

with *Azotobacter*, these cellulose-decomposing organisms stimulated the fixation of nitrogen, with cellulose as the source of energy, and 15 milligrammes of nitrogen have been fixed for each gramme of cellulose consumed.

Seasonal variation in nitrification.—Field observations on seasonal variations in nitrification have shown that the movement of soil water either upward or downward conduces to increased formation of nitrates. Such movement may be caused by drainage, surface evaporation or transpiration by plant, the last factor accounting for the greater total nitrification found in cropped as compared with fallow plots. The annual reestablishment of nitrifying flora takes the place of that eliminated by such adverse conditions as water-logging during the monsoon, and that, within limits, nitrifying bacteria can perform their specific function under conditions adverse to their multiplication.

Nitrogen fixation.—Nitrogen supply in the soil as affected by the intervention of micro-organisms, and the conditions under which the nitrogen of the air is fixed in soils in this country have been under investigation. Considerable fixation has been found to occur under suitable conditions, by the nitrogen-fixing members of soil flora and also through the intervention of leguminous and non-leguminous plants. The physiological activity of these organisms is controlled by soil conditions and by the availability of suitable nutrients for the organisms. *Azotobacter*, which can fix in the soil large quantities of atmospheric nitrogen, requires an abundant supply of carbohydrates. Intensive cultivation carried out without regard to this aspect of the case, results in the lowering of the supply of organic matter beyond the optimum point for nitrogen fixation and this source of cheap nitrogen supply to the soil would be cut off. Special attention is being paid to the study of the conditions under which nitrogen fixation takes place in Indian soils, with the object of determining the means of obtaining optimum conditions for fixation as a practical field measure. The very great variations in the amount of nitrogen fixed in the same soil in different years is indicative of the possibilities of influencing fixation by soil management without the necessity of adding expensive materials to the soil. The symbiotic relationship between green algae and nitrogen-fixing organisms has been studied. Algae are not usually associated with nitrogen fixation in pure cultures; but employing a technique, which excludes the possibility of symbiotic fixation, evidence has been obtained associating pure cultures of blue green algae with nitrogen fixation especially when the soil is exposed to sunlight.

Root nodule organisms of leguminous plants.—In studies on the fixation of nitrogen by leguminous plants it has been observed from

cross-inoculations of different strains of *Pseudomonas radicicola*, that in several cases very substantial increases in growth occurred both of roots and whole plants, although characterised by a complete absence of nodule formation. This occurred particularly with cultures from one kind of legume used to inoculate a different species. This phenomenon is usually explained on the basis that certain organisms, which are specific for certain plant groups in the Leguminosae, may not be able to cross-inoculate other groups of plants. On this assumption, the gram (*Cicer arietinum*) root nodule organism could be held as a separate strain different from all the other plant group organisms. But based on the experimental work and the observation that in India new leguminous crops can be grown without inoculation, it would appear that, apart from considerations of asymbiotical fixation, strains growing in association with different plants may develop strong symbiotic relationship with one plant group and a correspondingly weak one with others. In the latter case the roots of the host plant offer greater resistance to invasion by the organism and this results in the absence of nodule formation. An interesting and important observation was that in sand cultures no residual nitrogen was found in the culture sand in the case of *B. radicicola*, suggesting that fixation of nitrogen proceeded *pari passu* with its removal by the growing plant, unlike with *Azotobacter* culture.

Bacteriophage.—Root nodules of several leguminous plants have yielded bacteriophages capable of dissolving the strains of nodule organisms associated with the respective plants. It would appear that the 'phages are not specific for the particular strains and yet they appear not to cross-inoculate easily in some cases. For instance *Pisum arvense* bacteriophage has not been found to attack *Trifolium* or *Lathyrus* nodule organisms and *vice versa*. There is, however, effective cross-inoculation between the 'phages and nodule organisms of *Trifolium* and *Lathyrus*. Some legumes, *e.g.*, *Crotalaria juncea*, *Vigna catjang* and *Phaseolus radiatus* have not yielded bacteriophages from their root nodules. It is possible that the stage at which bacteriophage develops varies with the plant and its growth.

Among non-leguminous plants, maize roots have yielded a bacteriophage, which is less active than that from root nodules, but is capable of dissolving the cultures of *Trifolium* and *Lathyrus* root nodule organisms.

Bacteriophages isolated from different nodule organisms produce two different types of plaques. The type of plaque produced does not appear to depend either on the race of the bacteriophage or on the strain of the organism, but on the nature of growth. If the growth of the nodule organism is not slimy, plaques of D'Herelle

bacteriophage type are observed ; if it is slimy, raised and glistening, the type of plaque resembles a modified ' Twort ' phenomenon.

The medium used for the isolation of bacteriophage of root nodule organisms should not contain sugar, while another medium with 0·5 per cent sugar is necessary for enhancing the virulence of isolated bacteriophages. Nitrates and ammonium salts have been found even in small quantities to be adverse for the enhancement of virulence.

Bacterial dissociation.—Till recently the monomorphistic theory enunciated by Koch held the field completely. Koch has shown that under constant cultural conditions a pure culture of a bacterium is incapable of changing its form. Since 1911, however, the pleomorphistic theory concerning the nature of the morphological variations of bacteria has been gaining ground. The supporters of this theory noticed a great variety of cell forms in the life-cycle of organisms and they have shown that the changed forms can be stabilised. Filterable invisible forms of some organisms in addition to the great variety of the visible non-filterable forms have also been observed, and it has been demonstrated that by addition of certain chemicals to the cultures of some bacteria, they can be made to dissociate at will into filterable forms. The technique employed in proving this new pleomorphistic theory has been subjected to criticism and on that account the theory itself is attacked, but studies on dissociation of common soil bacteria, and human and plant pathogens, have lent additional support to the pleomorphistic theory.

Dissociation of azotobacter.—By several transfers of a laboratory culture of *Azotobacter* in marmite broth at pH 7·8, five dissociative forms of the organism could be observed on the 4th to 6th transfer. These organisms vary in their size and form and their powers of nitrogen fixation ranged from 0·05 mgm. to 3·40 mgm.

Dissociation of B. cereus.—*B. cereus* is an organism found to be constantly associated with mosaic of several cultivated plants. Inoculations with the organism, though successful in several cases (66 per cent), were not always successful in reproducing the disease, and hence nothing definite can as yet be said whether this associated organism is the real cause of the disease. The organism associated with mosaic of several plants has been identified as *B. cereus*. Its morphological characters and bio-chemical reactions have been further studied with reference to the various forms into which it can be dissociated. Bacteriophage or bacteriolytic principle is not present in its culture, and so it is probably not responsible for the dissociation. Six variants or dissociation forms of the organism have been obtained. Among these, the ' R ' form, which is non-motile and without pellucid dots in its agar growth, is a new

discovery. The filterable forms are found in a stabilised condition when the broth cultures of a normal culture of the ' S ' form (with pellucid dots) are filtered after eight days' incubation at 30°C. The cultures, if filtered before eight days, yield filterable forms, which show a tendency to revert to the ' G ' form and later to the orginal mother form 'S'. None of the variants shows the pellucid dots on agar growth— a peculiarity of the ' S ' cultures ; but it has been found that by growing the variant ' R ' in association with two other variants ' B ' (coccal rod form) and ' G ' (coccal form), the pellucid dots can be reproduced at will. The pellucid dots appearing on the culture of *B. cereus* are thus due to the rapid and spontaneous dissociation occurring in the cultures of the spore-forming mother form ' S '. Among the dissociated cells occurring in such a culture, if the cells of ' R ' form grow in close proximity with ' B ' or ' G ' forms the pellucid dots arise. In the light of these observations on the dissociation forms of *B. cereus*, some of the several variants, especially the filterable forms, singly or in combination with others, may be capable of reproducing mosaic symptoms more successfully than has been possible hitherto with cultures of the smooth variant.

Role of graminaceous crops and organisms associated with them in nitrogen fixation.—It is still uncertain whether plants of the Gramineae Order fix atmospheric nitrogen. But field experience and laboratory tests with crops like rice and maize have suggested that the crop fixes nitrogen probably with the aid of an organism associated with its roots. Preliminary experiments on the effect of the washings of the roots of maize at different stages of growth have given distinct indications that the maize root washings stimulate nitrogen-fixing organisms to fix more nitrogen in a culture medium. Recently, these experiments have been more critically carried out with organisms that survived washing the roots with the usual sterilising agents, and organisms have been found associated with the roots of wheat, rice and maize plants. Those associated with maize are still under investigation, but those associated with wheat and rice roots have been found to fix nitrogen. The amount of nitrogen fixed is of the same order as that of the legume nodule organisms.

MANURES, FERTILISERS AND PLANT NUTRITION

Manures and fertilisers.—Investigations on the composition and use of manures, fertilisers and studies on problems of soil fertility figured prominently in the programme of the work of the Institute from the beginning. Thirty years ago when the Institute commenced work, the use of indigenous manures was perfunctory and the use of artificial fertilisers was either unknown or was a novelty if they were used at all. To-day as the result of continued

and systematic research, fertilisers have come into extensive use in the country.

Analyses of soils supplemented by field observations in different parts of the country established general deficiency in organic matter, nitrogen and phosphorus. This observation was followed up by pot-culture studies and field experiments to test the effect of nitrogen, phosphate and potash individually and in different combinations, and to study by prolonged differential treatment the nature and effect of particular deficiency on crop yield and composition.

The factors concerned in the fixation of fertiliser constituents by the soil and the efficiency of these constituents as judged by their recovery in the plant have been studied with reference to soil type, soil conditions, moisture availability and climate. It may not be possible to control completely all these factors, but a knowledge of the interactions of these factors will be useful in drawing up fertiliser programmes.

Among the many lessons learnt from continuous experimental work, the most important is that crops respond most to nitrogenous manures and phosphates, the best results being obtained when used with organic manures. Fertilisers are most effective when adequate moisture supply is available and water is utilised most economically, provided it is available in sufficient amount, and the supply of nutrients is adequate. One of the functions of organic matter in the soil is to assist in the utilisation by plant of water and nutrients to the fullest advantage. Crop production with not only high yields, but also with high quality, is attained by the proper use of natural manures to supply organic matter, to improve C : N ratio among others, and then by the cautious use of fertilisers.

These observations call for the investigation of problems on the conservation and use of indigenous organic manurial resources. The conservation and use of cattle dung and urine, the composting of waste materials of the farm, simple methods for the crushing of bones and of solubilising their phosphates, the use of molasses, oil-cakes and other fertilisers have been investigated and methods suitable to the conditions of the Indian cultivator have been worked out.

The decomposition of green manures, exemplified by sunn-hemp (*Crotalaria juncea*), has been studied in the laboratory and in the field under varying conditions of soil moisture and depth of burying the crop in the soil. The results have made it clear that the value of green manure depends on its proper and complete decomposition, which is controlled by moisture conditions obtaining in the soil. The latter depend on the rainfall and on the transpiration of the green manure crop itself, which determines the amount of moisture left in the soil. An optimum concentration of nitrogen

in the soil is necessary for utilisation by the crop which succeeds the green manure crop. Measuring the resultant of a number of reactions, the failure to nitrify green manure has been traced to the reduction of nitrates in the presence of large quantities of cellulose and woody tissue, although these subsequently provide energy for nitrogen-fixing organisms. This explains also the residual effects of green manures.

The chemistry and technique of making composts have been investigated and the nature and rate of destruction of organic matter in soils and in composts have been studied. The processes are partly chemical and bio-chemical and consist of a low temperature period of chemical oxidation and a high temperature period of bio-chemical oxidation. The two are strongly activated by increase in temperature and aeration. The addition of fertilisers salts to the compost before the stabilisation stage results in the acceleration of the process of bio-chemical oxidation. Methods of storing farmyard manure and of composting waste vegetation have been studied and the conditions which develop fermentation and stabilisation with the minimum loss of dry matter and nitrogen determined. The addition of soluble nitrogen to the compost heap has been found unnecessary, as in the process of fermentation of the compost material all the added nitrogen is lost. Loss of nitrogen is to some extent related to loss of dry matter. It is not much till dry matter loss occurs to the extent of 15 to 20 per cent; beyond this the nitrogen loss is considerable. With cattle manure, loss of nitrogen is as great as 85 per cent under aerobic storage, while under anaerobic storage it can be kept as low as 15 per cent.

Plant nutrition.—The studies on the nutritional requirements of crop plants have shown that they vary in the requirements and capacity for absorption of fertiliser salts. The ratio of grain to straw and their composition varies with fertiliser treatment. The starch and protein content of wheat varied according as the phosphate or nitrogen was made available to the crop. With green manure alone the crop yielded grains richest in nitrogen, but poorest in phosphoric acid. When, however, superphosphate was added the results were reversed and grains richest in phosphate were obtained. Progressive increases of nitrogen as ammonium sulphate increased the nitrogen content of grain, but the phosphate content decreased as nitrogen increased. With phosphate, however, the result was to maintain the nitrogen level with a definite increase in the phosphate content of the grain and straw.

The most important result, which the studies in plant nutrition brought out prominently, is the knowledge that plant growth and development are two distinct phases of a plant's life. A plant

can grow tall and robust without the perfect elaboration of its products. This depends on the nature of nutrition given to the plant. In the early part of the plant's life the growth phase predominates and this period is marked by intense activity in the direction of building up complex products like protoplasm, complex carbohydrates and proteins. In the latter phase, the processes of hydrolysis, re-synthesis and re-elaboration predominate. Initial and inherent differences due to variety may affect the length of the first phase without necessarily and proportionately affecting the second phase, but the second is liable to be considerably influenced by the factors operating in the first phase. The gross organic and mineral composition of the foliage and grain may remain constant, but the make up of the several constituents vary.

Another line of investigation with an important significance is the role of organic manures, which is being studied by the workers at the Institute. Organic manures have been shown to take part in the direct nutrition of plant. It has been shown that crop plants absorb directly the products of decomposition, and it is believed that some of these are capable of stimulating growth and development and ultimately influence the quality of crop. This means that nutritional conditions for plants are associated with nutritional factors for animals. This new knowledge is of significance and has opened up a field of investigation for developing a system of crop nutrition, and thus to control soil conditions so that the end products of plant metabolism would be for the benefit of animal and human nutrition.

Soil fertility.— The supply of nitrogen to the soil and the maintenance of soil fertility is an economic problem of considerable importance to Indian agriculture. While the researches mentioned already show how to utilise the present available sources to greater advantage, attention is directed to the problem of maintaining the supply of combined nitrogen by biological agencies either independently or in symbiosis with leguminous plants. Due to causes which are not very clear at present, but probably due to biological agency, considerable fluctuations in the nitrogen content of the soil occur. In the experimental work done so far it would appear that with proper soil management considerable quantities of nitrogen can be fixed by biological agencies, and that most of it is capable of being utilised in practice if suitable methods of soil management are developed. Another important problem in connection with soil fertility is the supply of phosphates to Indian soils. The possibility of utilising soil organisms to make insoluble phosphates available to plants has been investigated and methods suitable for adoption in agricultural practice have been developed.

FOODS, ANIMAL NUTRITION AND DAIRY PROBELMS

Investigations on chemical problems relating to the nutrition of Indian cattle were commenced in 1920. This was subsequently shifted to Bangalore, but continued to remain as part of the Institute till the work was transferred to the Imperial Veterinary Research Institute in 1936. Numerous samples of food crops and fodders at the ripe stage and at different stages of growth have been collected from different parts of India and analysed for their chemical composition. The accumulated data have been published in agricultural ledgers and as bulletins of the Institute.

In India, the fixing of feeding standards for working animals and milch cattle is an important problem. Coarse fodders have been the subject of intensive study as they form the bulk of the ration, and malnutrition mostly arises from nutrient and mineral deficiencies in these roughages. The enquiry proceeded on four principal lines, namely, the determination of digestive coefficients of foods, nitrogen metabolism, maintenance rations and digestion of coarse fodders.

At first nutritional investigations were concerned principally with the study of the balance of intake and outgo, expressed in terms of energy or protein requirement. As work progressed and knowledge of the chemical nature of foodstuffs and metabolic processes advanced, it became apparent that a knowledge of total protein fed and the measurement of nitrogen balance were not adequate, that the biological values of foods and fodders should be known, and that mineral supply and balance was also an important consideration. A very large amount of data have been collected. Only a brief reference will be made here to some of the more important findings.

Maintenance tests with bullocks using rice straw or hay as the coarse fodder and a concentrate in the form of oil-cake for protein supply, have shown that rice straw fed to Indian cattle possesses a higher net energy value than American rice straw fed to American cattle. Again, Indian hay is more effective with Indian cattle than prairie hay is with American cattle though Indian hay is much inferior to good quality American hay as judged by analyses.

Studies on the digestion coefficients of fodders and concentrates have shown more efficient utilisation of roughage here than in American experiments. For example, while 72 per cent of fibre and 44 per cent of nitrogen-free extract of Indian rice straw are utilised by Indian cattle, the corresponding figures for American experiments are 59 and 46 respectively.

Investigations on nutrient requirements have led to the observation that food is more economically employed in milk production than for growth, maintenance or work.

Feeding tests with calves showed violent fluctuations in fodder consumption when the concentrate ration is low. When the proportion of concentrate was raised the fluctuations disappeared. This afforded a good index in fixing a suitable nutritive ratio by increasing the concentrate up to a stage at which fodder consumption becomes steady.

Rice straw provides just enough phosphorus to meet the requirement, but not enough lime. Sorghum straw provides both. Mineral supplement has no effect in places where enough of these is present in fodders.

A striking physiological fact brought out by experiments with rice straw is that it induces diuresis which is independent of the nitrogen excreted in the urine. There is a close relationship between potash content of straw and urine excretion.

Silage.—In a country like India, where extensive pastures and meadows are absent and where owing to limited monsoon period there is competition among grain, industrial and fodder crops, silage is a good approximation to green fodder which is so beneficial for all cattle, especially milch cattle. Ensiling different crops has been studied with reference to the number and kinds of bacteria and the acidity developed in the process. It has been found that while some crops like maize and sorghum can be converted into good silage, others like berseem and oats are unsuitable for the purpose when used singly. It has been observed, however, that two crops, each of which is unsuitable for making silage by itself, can give good silage when mixed in certain proportions, depending on the composition of the crops. A mixture of berseem and oats, for example, has given silage superior to that produced by either of these crops. The results obtained at first under laboratory conditions have been verified on a large scale in the farm pits. Addition of molasses to crops like berseem, *dhoob* grass (*Cynodon dactylon*) and kudzu vine, which are rich in proteins, also gives a better silage of good quality, because the addition of carbohydrates tends to encourage the lactic acid organisms at the proper time and to raise the acidity of the silage to the extent necessary to prevent the decomposition of the proteins by peptonising bacteria. The addition of molasses up to 10 per cent hastens lactic fermentation in silage making, brings about a rapid increase in H-ion concentration and total acidity, and thus renders silage less liable to damage by other fermenting organisms.

Milk of Montgomery (Sahiwal) cows and errors in milk records.—The milk of the Montgomery (Sahiwal) herd at Pusa was analysed

periodically and the errors accompanying such analytical values have been examined. For all the cows tested the morning milk yield was equal to that in the evening ; the differences if any were less than the probable error and were not systematic. The error of a single milking was about $\pm 0 \cdot 28$. The mean yield for either side of the udder or for morning and evening was derived from 10 to 15 milkings, and the error was less than $\pm 0 \cdot 1$. The mean percentage of fat in the milk of individuals varied from $3 \cdot 5$ to $5 \cdot 0$. The milk of different sides of the udder contained approximately equal percentage fat ; only one cow showed a systematic difference in this respect.

The fat content in the morning and evening milk respectively showed a systematic difference, that of the morning being always the richer. The solids-not-fat content of these milks was normal.

The variation in the fat content of milk with the period of lactation shows gradual rise between $2 \cdot 1$ and 11 per cent for Montgomery cows. For half-bred cows it was between $2 \cdot 2$ and $9 \cdot 5$.

The variation in freezing point among milks of Indian cattle is greater than has been found elsewhere, and it is a more delicate and surer test for added water.

Dairy hygiene.—Work in connection with dairying had been directed to dairy hygiene and to the methods of producing milk having a minimum of bacterial content. Clean milk equal to the standard of " certified milk " can be produced under Indian conditions. Cleanliness of dairy utensils and precautions to prevent contamination are the factors in the production of clean milk. An interesting and useful observation is that exposure of milking vessels to strong sunshine after thorough cleaning has a strong disinfecting action on pathogenic organisms.

Lactic acid organisms of dahi.—The physiology of lactic acid formers isolated from *dahi* (curdled milk), which is an article of food with many in India and is used as a starter for butter making in Indian homes, has been studied. There are two types of these organisms, the *Streptococcus lactis* and the other one of the *Bulgaricus* type. The one or the other preponderates according to the season and the starter preserves itself, by this means, without being lost in spite of wide variations in temperature. There is a yeast associated with these organisms in the *dahi*. Its functions appear to be (1) to keep under control the acidity which might otherwise kill the lactic acid organisms if it goes higher than what is tolerated, and (2) to invigorate the lactic acid organisms. The latter when grown in pure cultures die in about ten to twelve days either by their own reaction products or some bacteriophage associated with them. When the lactic acid organisms are grown with yeast the cultures survive for months and years. It has been found

that this property of invigorating the culture is not connected with the acid-reducing property of the yeast, since a *Cerevisae* type of yeast, which does not reduce acidity, has been found to equally invigorate the cultures of lactic acid organisms.

A lactic acid organism, which imparts an agreeable flavour to butter during the ripening of cream, has been isolated and has been used in dairies for making a product with a pleasing aroma.

CHEMISTRY OF CROPS

In addition to investigations on the absorption and utilisation of nutrients by crop plants, the biochemistry of several agricultural crops has been studied in respect to their storage and processing.

Rice.—The composition of the rices grown in Bihar and Orissa is in the main similar to that of other rices analysed by previous workers. When expressed as percentages of the dry matter, the sum of the albuminoids and soluble carbohydrates in husked rice generally lies between 94 and 95. There is relatively more phosphoric acid and potash in the bran than in the inner material. The nitrogen is more uniformly distributed. The greater acceptability of milled rice is therefore attained at considerable loss of mineral substances.

Tobacco.—The quality and yield of tobacco as influenced by manurial and other operations and the effect of different methods of curing have been studied. Cattle manure increased yield with thicker leaf texture and larger nicotine content ; superphosphate reduces nicotine, but affects the burning quality ; combination of saltpetre and superphosphate improves burning quality. In regard to curing, rack curing develops bright yellow colour and greater elasticity in leaf, reduces volatile nicotine, and contains a higher starch content compared to ground curing. The conversion of albuminoids into amides is one of the most important results of curing and fermentation. It would appear that the ratio of albuminoid to amide nitrogen and the ratio of ash to potash in the cured product form a fair index of the quality of the product than each of the constitutents independently. Comparative studies on curing leaves while attached to the stalk and detached from it, have shown that carbohydrates move into the stalk from the leaf while nicotine appears to do the reverse.

Studies on the factors responsible for the deterioration of cane and on the composition of such cane have been made. The deterioration of cane has been traced to the enzyme invertase and it has

been shown to be activated on rainfall and translocated from nodes to internodes.

The conditions under which cane can be windrowed successfully in the Peshawar valley as well as in Bihar have been studied. The chief factor which determines the length of time through which windrowed canes can be stored, is the incidence of rain, temperature being a secondary factor.

The effect of manurial constituents on the quality of the juice and on the *gur* produced have been studied. Treatment with superphosphate produced canes with the highest juice purity closely followed by canes treated with sulphate of potash. Sulphate of ammonia and calcium cyanamide depressed the sucrose content in the cane and increased glucose, whereas by using mustard cake the cane yielded juice of intermediate quality. The *gur* produced from the differently manured plots showed similar differences in respect to composition and quality.

Coloured canes like the Purple Mauritius variety are grown by the cultivator in certain parts of South India in preference to other varieties of cane. But the coloured canes have the defect that the sugar produced by the sulphitation process is of dull brownish colour, and, therefore, the factories do not wish to buy the cane although higher sugar recovery from such canes is assured. The chemistry of the sugarcanes responsible for the production of brown coloured sugar and the chemistry of the sulphitation process have been investigated, and a simple modification of the process suitable for adoption by factories without additional equipment has been developed. The modified process has been working satisfactorily in the factory where the trouble originally arose.

Potato.—The storage of potato through hot and moist summer months is an important problem connected with the potato crop. The chief difficulty is damage through rotting. It has been ascertained that the damage is at first physiological. Under closed storage temperature rises, respiration is activated, supply of oxygen through diffusion into tissues becomes inadequate. Catalase activity finally disappears and " black heart " develops. This is soon followed by rotting through external infection. Storage in sand on elevated ground is free from these disabilities. Early harvest potatoes keep better than those from late harvest.

Spices.—The antiseptic value of different Indian spices and of their essential principles has been investigated and the appropriate concentrations to be used for pickles and fruit juices have been found.

Vegetables.—Experiments on storing cabbage, cauliflower, turnips, carrots and other vegetables with the aid of *lactobacilli* have shown that this can be done easily on a small scale without the

necessity of elaborate arrangements or apparatus. The process is simple and consists in treatment with common salt equivalent to 2½ per cent on the weight of the vegetable. It is then stored air tight. Lactic acid fermentation sets in the juice of the vegetable extracted by the added salt, and this keeps for years if the bottle or the jar is air tight.

OR JAGGERY AND WHITE SUGAR MANUFACTURE BY THE OPEN PAN PROCESS

The manufacture of *gur* or jaggery from sugarcane is an ancient village industry. In spite of the stimulus given to white sugar manufacture on the factory scale and the phenomenal development of the industry in India within the past six years, two-thirds of the cane grown in India continues to be used in *gur* manufacture. The bulk of the population still consume sugar in the form of *gur*, and there is a good demand for the clean product with attractive colour. Most of the jaggery that is now produced is dark in colour, does not keep, and becomes soft and syrupy in the rainy weather. The importance of this industry to the farmer has been recognised and studied.

The chemistry of the process has been under study and various improvements have been evolved from time to time. Liming the cold juice to a point just above neutural or to slight alkaline reaction and the addition of a little phosphoric acid, barely sufficient to precipitate the excess of lime, yields a juice which can be concentrated to hard light coloured jaggery, with 80-83 per cent sucrose and 2 to 4·5 glucose.

A further and more recent improvement consists in the use of active carbon which can be produced in the village. In the new process raw sugar juice after heating and straining to eliminate foreign matter is poured on to a filter bed of activated charcoal. The juice, while passing through, is clarified and comes out clear and water white. When the juice has thickened sufficiently, it is ready either for conversion into *gur* or into white sugar in the ordinary way. Besides clarifying and decolourising the juice, treatment with active carbon raises the purity of the juice and also checks inversion on storage and during concentration.

The *gur* obtained by this process has an attractive colour, is hard and crystalline and keeps better. The *rab* by the carbon process matures earlier and gives an increased outturn of crystal sugar comparable in colour and analysis to good factory made sugar. The Department of Agriculture, Bombay, have reported a recovery or 8 per cent sugar on cane by this process.

The process for making the active carbon is simple and can be manufactured with equipment and resources ordinarily obtainable in a village or town and by a person of average intelligence and ability. The carbon can be used in *gur* manufacture from coconut and palm tree juices.

FERMENTATION PROBLEMS

Alcoholic fermentation.—A considerable amount of work on fermentation problems in India has been done, and knowledge of Indian yeasts obtained. Cultures of yeasts were supplied to some Indian distilleries and breweries. The experience gained is available for dealing with the problem of the manufacture of power alcohol from waste agricultural products.

Acetic fermentation.—The indigenous method of making vinegar from low quality *gur* or sugarcane juice is still prevalent to a great extent in India. This has been studied and it has been found that the method is crude and no precautions are taken in regard to cleanliness and purity of culture. Pure cultures isolated from the crude product gave from sugarcane juice a final product with a concentration of 7 per cent acetic acid in four days when the action of the yeast preceded that of vinegar bacteria and the fermenting medium is in thin flat layers. This technique has been used with sugarcane juice, solutions of *gur* and molasses. Similarly it has been demonstrated that various kinds of spoilt fruit can be successfully used for making vinegar of good quality.

BACTERIA ASSOCIATED WITH DISEASES OF PLANTS

The study of bacterial diseases of plants was one of the functions of the Bacteriological Section of the Institute till the year 1934, when the work was transferred to the Section of Plant Pathology.

Several varieties of diseased crop plants at Pusa and in other parts of the country have been investigated. The causative organisms have been identified in several cases after isolation and study of their morphological and bio-chemical characteristics and their association with the respective diseases established after inoculation and reproduction of the disease. Wherever possible suitable and simple measures of control, such as improvement in the drainage of soils, or ploughing in appropriate seasons have been suggested.

An interesting line of work is on the association of bacteria with ' mosaic ' disease of plants. An organism from mosaic affected tomato plants has been isolated, and by inoculation experiments the organism has been shown to be the causative agent in the production of mosaic symptoms in tomato plants. Extending the study to other mosaic affected plants, it has been observed that

B. cereus is often associated with mosaic affected plants. This organism has been found to dissociate in separate cultures and when two of the variants are grown together they gave rise to pellucid dots in the culture. Inoculations into plants of cultures of *B. cereus* have given erratic results. Some inoculations developed mosaic symptoms and some did not. Inoculations with cultures of the dissociative forms will show whether mosaic syptoms can be reproduced more successfully than has been possible hitherto with the inoculation of cultures of the smooth variety.

The association of bacteria with the 'mosaic' of sugarcane has been studied in greater detail and with results of considerable interest. An organism having a filterable stage of long duration and a bacterial stage of shorter duration has been isolated from mosaic affected sugarcane. It has, however, not been possible to reproduce the disease with inoculations of this organism, and direct proof associating the organism with mosaic virus is still lacking. Further work in subsequent seasons has shown that this organism is not present in mosaic affected cane at all stages of crop growth, as is evidenced from the results of experiments carried out month after month with fresh samples of healthy and mosaic affected sugarcane. In the set of cultures made between the months of April and June, *i.e.*, before the break of monsoon, the organism could be isolated, but between July and September the cultures did not develop the organism. In eight out of ten cultures made between April and June organisms with cyclostages could be isolated. It would appear that season and the stage of growth and development of the sugarcane plant have a marked influence on the cyclostages of the organism.

(*d*) INSECTS

(HEM SINGH PRUTHI, IMPERIAL ENTOMOLOGIST)

INTRODUCTION

In order to consider properly the entomological work carried out at the Imperial Agricultural Research Institute, it will be useful to review briefly the work done by various institutions in India prior to the inception of this Institute. Up to the end of the eighteenth century only about one thousand species of insects were known from India (Fabricius, *Ent. Syst.*), the representatives of which had been collected by various European visitors. During the first three quarters of the nineteenth century the progress in the study of Indian insects was slow but continuous, and a large number of scattered descriptions of Indian insects mostly collected by amateurs and named by specialists in Europe became available. At this time there was no entomological publication in the country

itself and hardly any investigation of the habits and life-histories of insects was in progress. Towards the end of the nineteenth century, however, a considerable amount of work began to be produced by workers in India. The monographic works of Atkinson, Wood-Mason, Swinhoe, Dudgeon, Hampson, Green, etc., on Lepidoptera and other groups of insects are well known. It was about this time that the importance of the study of insects and other animals of India was officially recognized, and the Secretary of State for India sanctioned the publication of a special series entitled the *Fauna of British India*, which is still in progress.

It was also in the last quarter of the nineteenth century that the immense economic importance of entomology began to be appreciated. In the year 1888 the Trustees of the Indian Museum, Calcutta, decided that, in addition to systematic work, investigations on insect pests of crops should also be undertaken by the Museum staff. During the following 12 years, Mr. Cotes, the Museum Entomologist, published a series of papers on several crop pests in five volumes of the *Indian Museum Notes*. In 1901, the Government of India sanctioned the post of Entomologist to the Government of India, with headquarters at the Indian Museum, Calcutta. On the establishment of the Imperial Agricultural Research Institute in 1905 the post was transferred to this new Institute and designated as the Imperial Entomologist.

COLLECTION AND IDENTIFICATION OF INSECTS

From 1905 onward, mostly due to the activities of the Entomological Section of the Imperial Agricultural Research Institute, the study of entomology in India started making very rapid progress. During the last 32 years a large and valuable collection of Indian insects, named with the help of well known authorities in various parts of the world, has been built up by the Section. In addition to numerous unnamed insects, the collection contains about 25,000 named species. Information about the time of occurrence, range of distribution, food plants, etc., of the species in the collection has been gathered and is being tabulated in the form of card catalogues. Summaries of available information, both published and unpublished, about the biology, control measures, etc., of the species of economic importance are being kept up to date. The collection with its relevant records is an extremely useful source of reference for not only the staff of the Institute but for all entomologists working in various parts of India, as no Provincial Department of Entomology is maintaining a collection covering the whole country. The utility of the Pusa collection which is one of the biggest of its kind in the East is not limited to India, but extends to neighbouring countries also, as a large number of insect

genera and species are common to Africa, India, the Federated Malay States and the Far East, and every year the Imperial Entomologist receives many enquiries from abroad about the exact distribution in time and space of various pests and parasites.

LIFE-HISTORIES OF INDIAN INSECTS

For the proper identification of related species and on account of the fact that we often receive from correspondents immature stages of insects for identification, the development and life-histories of various species have to be studied very carefully and minutely. Furthermore, as is well known, the study of the life-histories of noxious insects is very essential for devising suitable control measures against them. Therefore the Section has paid considerable attention to the study of the life-histories of Indian insects. Several thousands of insect species have been reared and illustrations of their immature stages made in the Insectary. The illustrations of various stages of crop pests as well as of the infested plants showing the nature of damage have been made in colour and published. The scientific results of the study of life-histories have been published in the form of monographs and memoirs covering several Orders of insects, *e.g.*, Microlepidoptera, Hymenoptera, Coleoptera, Diptera, etc. The colour plates of Indian insects are also very useful for teaching and demonstration purposes, and the Imperial Entomologist receives many requests every year from Provincial Departments of Agriculture, colleges, schools and other institutions for the supply of such plates.

SPECIAL INVESTIGATIONS

The staff of the Entomological Section is very small ; it is in fact smaller than that of several Provincial Sections of Entomology. It has never consisted of more than 3 or 4 gazetted officers and about half a dozen assistants. However, in addition to the work of fundamental nature described above, the staff has undertaken intensive studies of useful insects and of insects pests with a view to their control, and, in many cases, has been able to prevent considerable damage to crops and stored products. A brief account of such investigations follows.

Injurious Insects

Sugarcane borers.—Right since its inception the Section has paid special attention to the study of the identity, distribution, incidence and control of sugarcane borers, which collectively cause a loss of at least 10 per cent of the crop.

The identity of numerous species, previously all grouped under the name *Chilo* borers, was clarified and life-histories of various

species worked out. Regarding incidence it wa shown that the greatest damage by borers is done in early stages of the crop's growth when the season is hot and dry. Favourable climatic conditions on the other hand enable the crop to rapidly out-grow the attack. It has been further shown that the incidence of borers in October and ratoon crops is much higher than in February plantings. In addition to getting heavily infested themselves, the October and ratoon crops act as a source of infestation for the ensuing spring plantings. Besides clean cultivation—which includes prompt removal and destruction of trash and stubbles—avoidance of ratooning, early planting, spraying the young crop with a stomach poison to kill the first brood of young borers feeding on tender leaves, and collection and destruction of dead-hearts and egg-masses are measures which have proved very beneficial. During March-June 1931, 7,650 egg-masses of *Scirpophaga nivella* F. were collected and destroyed at Pusa, the average cost of collection being only $4\frac{1}{2}$ annas per acre per month.

Borers have been found to be heavily parasitized by several indigenous parasites, which have been studied in some detail and appear to be of potential value as controlling agents of the pest.

Cotton bollworms.—Cotton is attacked by the pink bollworm (*Platyedra gossypiella* Saund.) and spotted bollworms (*Earias insulana* Boisd and *E. fabia* Stoll.) in all parts of India. The larvae bore into the shoots, flower buds and bolls and reduce the formation of healthy bolls and cause deterioration in the quality of the lint by staining. The cotton crop in the Punjab in 1905 and in Sind in 1906 failed completely due to the attack of the spotted bollworms. In 1905, the damage caused by these pests was estimated at 3 crores of rupees.

The earliest work on cotton bollworms in India was carried out at Pusa to study their life-history, distribution and natural enemies. Trapping the moths in the Andres-maire traps and medusa lamp traps was tried. Experiments were performed to determine the effect of thick and thin sowings and sowing cotton mixed with another crop, *e.g.*, *tur* (*Cajanus Cajan*). Several parasites of the pests were reared, and a study was made of the habits and alternative hosts of *Microbracon lefroyi* D. × G., a parasite still considered to hold some promise for the control of bollworms. These early investigations have formed the basis of much of the present-day work on these pests.

The Bombay locust (*Patanga succinctum* Linn.).—Early work (1903-05) carried out at the Institute on the life-history, habits and methods of destruction of this locust has helped good deal in formulating control operations against this and other locusts. The investigation showed that locust outbreaks occur periodically,

that in order to fight them successfully the control measures must be concerted, and that the collection and destruction of pairing locusts and their egg-masses are very useful control measures. During the 1903-05 campaign, 4,152 maunds of locusts, equivalent approximately to 664,32,000 individuals, and 100 maunds of eggs numbering about 400,000,000 were destroyed. Likewise, 13,252 maunds of hoppers, representing well over 930 million individuals, were destroyed by driving them into trenches and burying them therein.

Gram cutworm (*Agrotis ypsilon* Rott.).—At the request of the Department of Agriculture, Bihar and Orissa, an enquiry was taken up into the enormous damage caused by cutworms to *rabi* crops year after year in the Mokameh tal land. The investigation showed that a single female of this moth produces progeny which will consume about $1\frac{3}{4}$ lb. of green leaves. The damage actually done, however, is much greater as the larvae eat much less than what they destroy on account of their habit of cutting down the whole plant. A noteworthy feature of this pest was its occurrence in lands which were flooded during the previous *kharif* season. The picking off of the first brood caterpillars and setting up of Andres-maire traps reduced the damage to such an extent that out of a total area of 20,000 bighas which used to be affected in the previous year, only about 2,000 were affected. A similar campaign was undertaken against the pest at Golgong and Ghogha with the result that the affected area which normally extended over 8,000 bighas was reduced to about 20 bighas only. (*Ent. Mem.*, Vol. 1.)

Rice jassids (*Nephotettix bipunctatus* Fab.).—In 1914 this pest was reported to have damaged 300,000 acres of rice, causing a loss of approximately 14 million rupees in the Chhatisgarh division of the Central Provinces. Early maturing varieties of paddy suffered less than the late maturing ones. A study of the habits of the insect disclosed a strong predilection of the adults for light. The setting up of light traps in the fields was, therefore, recommended as one method of control. Clean cultivation, the free grazing of cattle in the harvested areas, as well as in the dry beds of ponds and streams where grasses grew luxuriantly, and bagging the nurseries with hand-nets, or long pieces of cloth previously moistened with kerosine oil, were also recommended as control measures.

White ants.—A large series of experiments was carried out on the preservation of wood and other materials from the attacks of white ants. The efficacy of various commercial preparations was tested and the relative immunity of different kinds of wood was determined. It was found that some pieces of 'Powellized' wood even were attacked by *Microtermes obesi* Holmg., and the

process, therefore, was not so infallible as was claimed. Freedom from attack was also found to depend upon the variety of wood itself, the method of treatment, and the preferential tastes shown by the various species of termites locally prevalent in the area.

One of the important crops attacked by termites has been sugarcane. Experiments carried out before 1917-18 showed that the liability of cane to damage by termites depended largely on the moisture content and texture of the soil in which it was grown, sandy soils being more favourable to the development of this pest, and the amount of damage did not depend merely upon the presence of the insect.

The life-cycle of the largest of the five termite species known to occur at Pusa, *viz.*, *Odontotermes assmuthi* Holmg., was studied in 1914 for the first time.

Linseed midge (*Dasyneura lini* Barnes).—This pest, new to science, was first noticed at Pusa damaging the flower buds of linseed in 1933, when the attack was about 50 per cent. The larvae of this midge feed upon the sap of essential organs of the flowers with the result that the latter become emaciated, fail to open and consequently setting of seed does not take place. The anatomy, life-history and bionomics of this pest have been worked out in detail (*Ind. Jour. Agric. Sci.*, 1937).

Indigo Psylla.—At the request of the Bihar Planters' Association, an investigation into the Psylla disease of indigo was carried out. It was found that only the indigo-yielding plants and none of the weeds which commonly grew in indigo fields served as food-plants of this insect. Manuring the plants with superphosphate and oil-cake made no difference in their susceptibility to attack by the pest. A study of the life-history of the insect revealed the necessity of establishing a close season. Cutting every plant level with the ground at the time of harvest without leaving any green leaves or shoots, was also found to be an effective preventive measure. The direct mechanical remedy of cutting off the tips of the plants and placing the cuttings in boxes in which the psyllids could be killed after the emergence of their parasites was also found effective.

A soap spray (1 lb. to 12½ gallons of water) to kill the nymphs and adults was found useful.

Tea and coffee pests.—Pests of coffee were investigated in Mysore and the Nilgiris in 1904-05. An inquiry into the best method of checking thrips on tea in the district of Darjeeling was taken up by arrangement with the Scientific Officer of the Indian Tea Association.

Coconut caterpillar (*Thosea unifascia* Walk.).—A complaint of a serious outbreak of this pest of coconut palm was received from Andamans. The area was visited and the pest was closely studied.

Remedial measures which consisted of cutting and burning the leaves on which caterpillars had congregated, destroying cocoons and capturing moths by light traps were carried out.

Fruit pests.—Insect pests of fruits in India have remained, until recently, very much neglected. Large number of enquiries have been received from individuals as well as officers of Agricultural Departments in the N.-W. Frontier Province and Baluchistan where fruit culture is a very important occupation of the people.

Surveys of the insect pests of fruits and fruit-trees were started in these provinces in 1931 by the staff of the Imperial Entomologist, and we now possess a fair knowledge of the distribution, status, etc., of these pests. An annotated list of the fruit pests of North-West Frontier Province dealing with distribution, nature and extent of damage, etc., of over 50 different species has been prepared. Of these, the most important are the Codling moth, San Jose scale, Apricot chalcid, Fruit flies, etc.

The Codling moth (*Laspereysia pomonella* L.), a notorious pest of apples and other fruits in several parts of the world, was hitherto unknown from India. In 1900 there was a doubtful record of this pest from Kashmir but in 1935 the Imperial Entomologist recorded definitely the pest from Baluchistan and in 1937 in the N.-W. Frontier Province. A warning was issued and the Imperial Council of Agricultural Research have sanctioned a scheme for an intensive survey of the pest.

The San Jose scale (*Aonidiella perniciosus* Comst.) is another serious pest which has come to India recently. At the request of the Kashmir State Government an investigation was conducted on this pest in the Kashmir valley and control measures (spraying) were carried out.

The Apricot chalcid (*Eurytoma samsonowi* Vas.) was first discovered in 1912 damaging stones of apricot fruits in the N.-W. Frontier Province. It is serious in certain varieties.

The fruit flies (*Chaetodacus ferrugineus* Fabr. and *C. zonatus* Saund.) do considerable damage to several fruits, *e.g.*, peach, guava, pear, etc., in various parts of India, and numerous sprays and poison baits have been tried against them. Experiments on the chemotropic reactions of the fly showed that oil of citronella or its constituent eugenol (C_{10} H_{12}. O_2) exercises strong attraction for the flies. The citronella baits, therefore, constitute not only a means of detecting the presence of flies in a locality with a degree of certainty not easily attained by ordinary methods of observation, but also form the basis of a cheap and simple method of control. Using this chemical it was possible to determine the limits of distribution of this fly in the course of a tour of various provinces.

A poison spray (lead arsenate, molasses and water), which depends for its efficacy on the habit of the fly of sucking any drop of moisture on leaf, has been discovered and tried with beneficial results, reducing damage in orchards from 45—60 per cent to 2 per cent. Its comparative cheapness in relation to the value of the crop greatly adds to its excellence as a measure of control.

Pests of stored products.—During 1915-16, over 60 different products were placed under ordinary storage conditions for the observation of their insect pests. The method of storage under a layer of sand gave good results, the grains and pulses remaining perfectly safe and in good condition. Experiments on the storage of food-grains in the presence of mercury showed that this substance in the form of free mercury or of mercury-tin amalgam is effective in preventing the breeding of insect pests of food grains and that mercury in the latter form has no deleterious effect either on the germination of the grain or on the health of the consumers.

The effect of sunning pea seeds (*Pisum arvense* L.) affected by *Bruchus affinis* Frol. was found to be distinctly beneficial, as it reduced the incidence of the pest by about one-third.

A recent study of the influence of various humidities on the biology of the common grain weevil (*Calandra oryzae* L.) has yielded some interesting results, the most important of which is that the pest cannot flourish at relative humidities below 50 per cent.

During 1907-09 the centres where army stores are baled were visited to investigate the occurrence in clothing, etc., of the destructive insect *Anthrenus fasciatus* Hbst., and recommendations were made for better baling.

The Cigarette beetle (*Lasioderma testaceum* Duft.) and its grub injure cigars and cigarettes by boring into them and also damage cut and uncut tobacco and other stored products. Owing to the serious attacks the trade in cigarettes is considerably interfered with. A large firm in Calcutta manufacturing about two million cigarettes daily complained to the Imperial Entomologist that their factory had become badly infested with this pest, the total loss amounting to between seven and eight *lakhs* of rupees. The factory was going to be closed. The factory was inspected and a process of fumigation (carbon bisulphide) was recommended and the firm had no further trouble.

Useful Insects

Another line of work which has received considerable attention at the Institute is the study of lac cultivation, silkworm rearing and beekeeping. As a result of several years of pioneer experimental work carried out by this Institute, these three cottage industries, which are primarily dependent on insect activity, are

now more or less on scientific footing. This is especially true of lac and sericulture. A brief account of the work is given below.

Silkworm rearing.—The encouragement of silk industry and the cultivation of Eri silk was one of the first items on the programme of this Institute. Investigations to determine the possibilities of Eri silk cultivation in the plains of India were undertaken in 1907. Rearing of Eri worms was done under conditions of cottage industry, and spinning, dyeing and weaving of the Eri silk were also undertaken. The manufactured silk won prizes at several exhibitions, and thus the rearing of Eri worms received a great impetus. Distribution of disease-free eggs was carried out for sometime and several young men were trained in the work.

Similar investigations were carried out in connection with mulberry silk-worm rearing, the improvement of reeling, eradication of the pebrine disease, and hybridization of the worms.

Early work on mulberry silk cultivation concerned itself with the hybridisation of varieties with the object of producing a superior silk-producing multivoltine hybrid. The cultivation of a hybrid between the European univoltine worms and the Bengal multivoltine gave good results. Experiments were also made on the crossing of Italian and French univoltine mulberry silkworms with all the available indigenous multivoltine races. As these mongrel crosses gave greater yield of silk in the first generation than in subsequent ones, attempts were made to prevent this deterioration by the infusion of new blood in the mongrel races.

The work created considerable interest among the people, advice was sought and given, and as an additional impetus seed was supplied free for some time to all those who asked for it.

Improved reeling machines were designed and sold to the public in large numbers. For 15 years (1907-22) the Section rendered help to the Provinces, Indian States and private individuals on problems connected with sericulture, and trained students. In 1922 the sericultural work after having been placed on a scientific footing was handed over to the Department of Industries of Bihar and Orissa.

Lac cultivation.—Investigations were started in 1907 to work out the life-history of the lac insect, study its enemies, discover the best methods of propagation and cultivation, establish the possibilities of lac-culture as a cottage industry, and place lac production on a scientific basis. The results of the experiments in these directions were published in the Pusa Bulletins Nos. 28 (1913) and 142 (1923) entitled " Cultivation of Lac in the Plains of India ". In 1923 the Indian Lac Association was started and the services of the First Assistant to the Imperial Entomologist, who had been

engaged for several years on investigations in connection with lac cultivation, were placed at the disposal of the Association for sometime.

Apiculture.—During 1910 and 1911 strains of Italian and Americ-Italian bees were imported from England with a view to ascertaining the possibilities of apiculture in the plains of India. The attempts were successful in so far as the production of honey was concerned, but it was not possible to obtain fertilized queens, apparently owing to the action of bee-eating birds, and the colonies came to an end in 1913. In 1912 an attempt was made to domesticate the common Indian bee (*Apis indica* F.) on modern lines, and prepare proper " comb-foundations ' for this bee. A special machine was obtained and ' foundations ' are now being supplied to people all over the country. A bulletin on modern methods of bee-keeping was published in 1915, which is still the only important source of reference to bee-keepers in India and is therefore in great demand. This has since gone into a revised second edition as Misc. Bull. No. 6, 1936, of the Imperial Council of Agricultural Research. For want of a special apiculturist the scientific work in bee-keeping was discontinued.

Biological control.—The practice of employing insects to destroy plants and insect pests has come to the fore only very recently, but the idea is old and the possibility of utilising this method of control has been kept in view since almost the inception of the Institute.

In 1907-09 parasites occurring in South India were supplied to Prof. Silvestri to aid him in his fight against the Olive fruit-fly, a serious pest in Italy. Later (1909-10) parasitised cotton bollworms were sent to Ceylon and Egypt to introduce the parasite in those countries. *Rhogas* sp. obtained from parasitised bollworms were bred and tried in the experimental area at Pusa. In 1915 *Rhogas* pupae were sent to the Punjab to assist in establishing the parasite there. A study of the parasites of *Chrysomphalus* (=*Aspidiotus*) *aurantii* Mask., commonly occurring on *Citrus* spp. and roses at Pusa, was started with a view to sending them to Italy. Parasites for the control of *Coccus viridis* Green in the coffee districts of Southern India and of *Dialeurodes citri* Ashm. for exporting to Florida were also collected.

Biological control has succeeded in several countries where other methods have failed, and has appreciably reduced the bill for recurrent control measures. Realising its suitability for some of the notorious pests in India, a systematic survey and study of the parasites of some of our common crop-pests has been started during the last few years. It is obvious that a thorough knowledge of the indigenous parasites and of the check they exercise over

insects, pests or otherwise, must be the first preliminary to any enquiry into the possibilities of controlling an insect pest by means of its natural enemies. So far observations have been made chiefly on parasites of sugarcane borers and fruit-flies.

The eggs and larvae of the sugarcane root-borer (*Emmalocera depressella* Swinh.) have been found parasitised by *Trichogramma minutum* Riley and *Glyptomorpha deesae* Cam., respectively. The stem-borer (*Argyria sticticraspis*) is parasitised by *Apanteles flavipes* Cam. late in the season. Two Encyrtids (*Tetrastichus pyrillae* Crawf., and *Ooencyrtus pyrillae* Crawf.) are important parasites of eggs of *Pyrilla* sp., 22-70 per cent of the host being attacked by them in nature. The Dryinids (*Dryinus pyrillae* Kieff., and *Chlorodryinus pallidus* Perk.) attack the nymphs of *Pyrilla* sp., and seem to be of considerable potential value and warrant a thorough investigation. The top-borer is parasitised in the field by *Rhaconotus scirpophaga* Wilkson. The Broconid *Apanteles paludicolae* Cam. is a serious enemy of *Sphenarches caffer* Zell., a pest of leaves and pods of several cucurbits. Besides these, *Pareuderus torymoides* Ferr., an egg parasite of the Amaranthus weevil borer, *Lixus truncatulus* F., and some chalcid parasites of *Agromyza obtusa* Mall. and *Dasyneura lini* Barnes have been studied in detail.

In 1935 the study of *Opius fletcherii* Silv., an important parasite of fruit flies, was undertaken at Pusa at the request of the Entomologist to the New South Wales Government who wanted to introduce this parasite into his country.

Lantana aculeata, a plant with rather pretty flowers, was originally a native of America but is now distributed all over the tropical world. Introduced into South India about 1824, in due course it grew to the proportions of a pest and defied the usual methods of mechanical eradication. Early in this century, entomologists in Hawaii, Fiji and Australia were already testing or considering the possibility of controlling this pest through the agency of insects. The seriousness of the situation in South India led to a similar enquiry in 1916 when an intensive survey was undertaken and a long list of insects attacking *Lantana* was brought to light. The most efficient of these was the Plume moth (*Platyptila pusillidactyla* Wlk.), but the presence of its parasites greatly detracted from its value. The net result of the investigation revealed the absence of any indigenous insect capable of checking the spread of *Lantana* in India. The enquiry also seemed to suggest that the importation of a seed-fly (an Agromyzid) would effectively control the pest as it had been reported to do in Hawaii.

INSECTICIDES

The use of poisons for the destruction of insect pests is a common practice in modern agriculture. Up to 1912 arsenic-containing chemicals were the chief insecticides employed on a large scale in India. Apart from the toxicity of these insecticides to higher animals, certain of them were found unsuitable under Indian conditions. It was discovered, for instance, the lead arsenate when used under high temperatures rapidly decomposed with the formation of soluble arsenic. A search for a better insecticide, therefore, resulted in the discovery of lead chromate, a highly effective insecticide. This compound acts both as a deterrent as well as a stomach poison and can well replace arsenical insecticides. It is easily made in paste form and its yellow colour enables it to be readily seen on sprayed foliage. Being extremely insoluble, it does not injure the foliage and is also not easily washed away by rain. At 1 lb. in 32 gallons of water it is safe to use, toxic to caterpillars and a powerful deterrent. (*Ent. Mem.*, Vol. IV, 1912.)

A STUDY OF THE FOOD OF BIRDS IN INDIA

The value of birds to agriculture is determined largely by the nature of their food. Broadly speaking, a bird is useful if it feeds upon injurious insects, harmful if its food consists of useful insects such as bees or of plant products such as young fruits, seeds, flower-heads, etc. If it partakes of both types of food its usefulness or otherwise will naturally depend upon the balance of its potentiality for doing good or causing mischief. An example of such a bird is the Rosy Pastor (*Pastor rosens*) which does considerable damage to ripening sorghum, and at the same time is very destructive to locusts. It is therefore a matter of importance to ascertain the exact nature of the food of such birds. Field observations on the food of common birds have, therefore, been a routine operation of the Section, and this was supplemented by an examination of their stomach contents. Altogether 1,325 birds were thus examined and an analysis of their swallowed food was of great value in preparing a list of useful and harmful birds (*Ent. Mem.*, Vol. III, pp. 1-371).

INSECT CARRIERS OF DISEASES

(*i*) *Animal diseases.*—The first insects to claim attention belonged to the genera *Stegomyia* and *Phlebotomus*. In view of the danger of spread of yellow fever in India experiments in the methods of controlling *Stegomyia* were undertaken at Pusa. The method adopted was the filling up, with earth or plaster of Paris, all known or probable breeding places. Early observations also showed that powdered calomel has many of the properties of the ideal mosquito

larvicide, and although its action is slow it is lasting, and the amount which it is necessary to use is so minute that treated water is in no way harmful or uncomfortable for use by men or cattle.

An important advance in anti-mosquito work was the provision of such breeding places to the mosquitoes as could be under control and from which larvae could not be allowed to reach maturity. It was felt that this method would be a useful supplementary to the ordinary destruction of natural breeding places of the mosquitoes.

The life-history of three species of *Phlebotomus*, namely, *P. papatasii* Scop., *P. argentipes* Ann. & Broom., and *P. minutus* Rond., was worked out. Observations on the last mentioned species led to the view that the house lizard was the real host of the sand-fly and its connection with man was merely of a secondary nature.

Various Tabanidae occurring at Pusa were under study for several years. Investigations in connection with Surra disease showed it to be capable of being transmitted by *Tabanus albimedius* and *T. straitus* Fabr., and that the disease is not transmitted heriditarily to the progeny of infected females of these insects.

A large number of experiments carried out on the behaviour of bed bugs under varying temperatures established the fact that a two minutes exposure to a temperature of 52°C. is generally sufficient to kill the pest.

Recently the attraction of certain indigenous materials, such as toddy, milk, curd, *gur*, mustard oil-cake, stale meat and fish, to house and blow flies was tested with a view to evolving an efficient fly trap. Mustard oil-cake and stale meat or fish gave the best results, and a cheap fly trap has now been devised with one of these substances as an attractant. (*Ind. Jour. Agri. Sci.*, 1935.)

Another problem which has received close study is the discovery of the insect vectors of virus diseases of tobacco. Rapid progress has been made in this line of work; an important insect vector and one or two alternate plant hosts of the viruses have been discovered. (*Ind. Jour. Agri. Sci.*, 1937.)

STUDY OF INSECTS UNDER CONTROLLED CONDITIONS

During the last few years the Section has started work on the ecology and epidemiology of insect pests, a problem of fundamental importance, which has not yet been investigated in any other part of the country. For devising proper preventive and control measures against insect pests it is essential to ascertain the exact environmental conditions (especially temperature and humidity)

which are most suitable for their growth as well as those which adversely affect their development. Therefore several important insects have been studied carefully and their threshold of development, the upper vital limits and powers of fecundity determined in reference to the factors named above. (*Proc. Nat. Inst. Sci. India*, 1936.)

(*e*) PLANT DISEASES

(M. MITRA, ASSISTANT MYCOLOGIST)

INTRODUCTION

Intensive work on fungi began in this country with the appointment, in 1901, of Dr. E. J. Butler as Cryptogamic Botanist to the Government of India. Prior to this, pioneering work had been done by two army medical officers, Major A. Barclay and Dr. D. Cunningham, whose contributions on rusts and mucors are considered as classical. A genus of Mucorales, *Cunninghamella*, was named after the latter officer.

In 1905 Dr. Butler was transferred to Pusa as the Imperial Mycologist when the mycological work at the Imperial Agricultural Research Institute was formally started. In those early days the botanical departments in the universities and colleges were just being organised and the agricultural colleges were yet to be started. Dr. Butler's first task was therefore to train a band of workers, in the methods of botanical and mycological research, to assist him in his investigations. Many young men who obtained such training under his inspiring lead later went out to the provincial departments of agriculture as mycologists. This activity has continued to be maintained, and students come here to learn mycology and pathology and conduct investigations in its well-equipped laboratories.

The main lines along which this work has progressed in the course of thirty-two years and the reaction of that work on the development of mycology and plant disease investigations in India and on mycological thought abroad are given in this account. The chief function has consisted in studies of diseases of crop plants caused by parasitic fungi. The life-history of the fungi causing the diseases and the relationships of the fungi to their host plants have been elucidated, and in many cases means of combating the ravages of the diseases have been suggested or worked out in detail. The crops whose diseases have been dealt with are cereals, millets, sugarcane, pulses, vegetable crops, oilseeds, drug plants, spices and fruit trees, etc. Some other organisms that cause loss to plants have also been studied. Examples of these are the 'Uffra' disease

of the rice plants caused by a nematode worm, *Orobanche* a flowering plant parasitic on tobacco and plants of the cabbage and potato families, an alga that damages the leaves of the tea-plants, mangoes, etc., and virus diseases of sugarcane and sandal tree.

PLANT DISEASE SURVEY

Before 1905 hardly anything was known regarding the fungous diseases affecting crops that are grown in this country. A few observations had been made by the Reporter on Economic Products but they were necessarily rather meagre. A knowledge of tropical fungi and the diseases they caused was also in its infancy. Mr. T. Petch, who has made substantial contributions about Ceylon Fungi, had just been appointed across the seas. Indeed the science of plant pathology itself, as distinct from mycology, was in its infancy.

The earliest work of the mycological staff was to tour the country extensively, collect diseased plants at appropriate seasons, make observations on them and find out which were relatively more destructive and needed earliest attention. Above all the associated fungi had to be identified. Because of the lack of proper literature and a herbarium with identified specimens, the collections were sent abroad to distinguished mycologists and with their aid the beginnings of a National Mycological Herbarium were made. The series of articles by Sydow and Butler, 'Fungi Indiae Orientalis' that appeared between the years 1904 and 1915 laid the foundation of Indian mycology and prepared the ground for 'Butler and Bisby's Fungi of India' and its first supplement. Several new genera and new species were found, many of which are now known to be of wide occurrence. Much of this work is of economic value in that it determines whether or not parasitic fungi on weeds and non-crop plants have any connection with those parasitic fungi that are actually causing disease in economic crops and so prevent unnecessary investigations being made on parasites that are allied but not identical. This knowledge is especially valuable while one is working out measures of control or eradication.

By the end of 1920 nearly 1,800 species had been collected, identified and several of them studied in detail. This survey work has been continued, as circumstances permitted, and several fungi, in the neighbourhood of 200 species, have since been recorded. Considering that the total number of fungi recorded for India so far (end of June 1937) is about 2,810, this is no small contribution from the Institute. The Section has also received in exchange from neighbouring countries such as the Philippines, Java, Straits Settlements, Japan and also from Australia, New Zealand, Central Europe and the United States of America, collections of parasitic

fungi of economic importance in those regions. The herbarium is invaluable for comparing disease-causing fungi of this country with those of other countries, and so enabling us to make use of the work done and the experience gained by foreign mycologists. A catalogue of all the specimens in the herbarium compiled chiefly for the benefit of workers in the provinces and universities was printed in 1921 and a supplementary list is being prepared.

PLANT DISEASES

Blights and Downy Miedews

Prior to his taking up duties in India, Dr. Butler had studied the water moulds and related fungi (Pythiums, Chytrids, etc.) in Great Britain, France and Germany. With the knowledge which he had gained abroad, he studied these fungi of India and one of his earliest memoirs was 'The Genus Pythium and some Chytridiales'. The knowledge of the group, which was in chaos, was placed on a sound basis and the classification perfected. With the passing of the years and the gaining of more knowledge, it has been found that the views propounded then are even now not easily assailable. The memoir is now a classic.

Important contributions on other Pythiums have continued to be made and some, like *Pythium graminicolum* Subramaniam, discovered and studied at the Institute, have been found to cause root-rot diseases in Hawaii, the Philippines and other tropical countries. *Pythium aphanidermatum* first studied on ginger, papaya, etc., and later on cucurbits has been found to be a common organism doing damage to various crop plants.

It is natural that the genus *Phytophthora*, which is allied to the fungi discussed above, should also receive attention. Up to 1910 it was generally believed that the bud rot of palms and rot of coconuts were due to bacteria, and Johnston had written an extensive bulletin for the U. S. Department of Agriculture ascribing these diseases, occurring in the Philippines, to *Bacterium coli*. It remained for this Institute to point out that in India at any rate the causal organism was a fungus, now called *Phytophthora palmivora* Butler. It is now recognised to be true outside India also wherever these palm diseases occur. This work of the Institute had thus a profound effect on tropical mycology. The operations to check the diseases in the Godavari delta initiated by the Institute saved the crop from total extermination and indicated what concerted action could do to eliminate diseases.

Another *Phytophthora* discovered, investigated and named at this Institute is *Phytophthora parasitica* Dastur. It has now been

found to be of wide occurrence in the tropics and semitropics with a large host range, and the work done on it here has led to a proper understanding of the diseases caused by it in several other countries.

Phytophthora colocasiae, discovered and named in Java, was studied in detail, and though the work was done twenty-five years ago, no further knowledge has been added to what was then reported with regard to this disease.

Phytophthora infestans, the organism causing late blight disease of potato, also received good deal of attention. It was found that the fungus does not survive in the heat of the plains of India and is ordinarily restricted to the Himalayas, Khasi and Nilgiri Hills, but periodical outbreaks have been observed in the plains. An analysis of the conditions leading to these attacks indicated that long exposure to temperatures above 77°F. is fatal to the fungus. The investigations carried out showed that whenever infection took place in the plains infected seed from the hills had been used, the seed having been imported just before the sowing time when the temperature on the plains happened to be below the thermal death-point of the organism concerned. Further, it was observed that if infected seed from the hills must be used in the plains, it should be obtained fairly early so that it may be exposed for a month or so to the summer heat.

Yet another Phycomycetous genus of wide-spread occurrence is *Sclerospora*. While taxonomical work had been done in other countries on the species of this genus, the first pathological reports appeared in about 1910 from the Institute.

Wilt Diseases

One of the earliest pathological investigations taken up for study at the Institute was the wilt disease of pigeon-peas. In the United States it was believed that the causal organism was *Fusarium vasinfectum* and that its perfect stage was *Neocosmospora vasinfecta*, whose perithecia occurred on the surface of the affected plants. This led to considerable confusion until it was demonstrated at this Institute that the two fungi were *not* one and the same. This was later confirmed by Higgins in America. Recently resistant varieties have been developed by the Institute, and it has also been shown that phosphatic manures render the plants susceptible to this disease. Other wilt diseases have not been neglected. The first work on cotton wilt in India was done sometime in 1912 at Pusa, and recently the wilt disease of sunn-hemp, *Sesamum indicum* and other crops has also been investigated.

Foot and Root-rots

One of the destructive parasites occurring in Indian soils as elsewhere is *Rhizoctonia solani*. Two memoirs comprising the work

done on this and allied fungi have added not only to our knowledge of these fungi but of workers outside this country also. Sclerotial rots in rice due to these organisms have been investigated, the role of different associated organisms determined, and our knowledge of these placed on proper basis.

Among the most destructive foot-rot diseases, that of betel vines due to *Rhizoctonia solani* and *Phytophthora parasitica* are the most serious. The exhaustive work done by the Institute on this disease for the Bengal Department of Agriculture has led to the adoption of appropriate control measures and the disease has now been brought under control.

Foot and root-rots of cereals especially those of wheat and barley caused by species of *Helminthosporium*, especially *H. sativum*, have been investigated and proper control measures have been suggested.

Leaf spots

Leaf spots due to several different fungi cause enormous losses to cereals, and among these the spots due to species of *Acrothecium*, *Helminthosporium* and *Alternaria* are of major importance. Considerable time has been spent on the taxonomy of these fungi and also on methods for controlling these diseases. As a result we have now a clearer conception regarding them and in some cases know also how we can avoid these diseases. In this connection much work on dissociation or saltation of these fungi has been done to see if more pathogenic forms or races are produced in nature by a composite species. While no such dread need be entertained, the scientific value of these facts is of outstanding importance. In several cases it has been found that these fungi have a wide host range including several wild grasses which serve as source of infection.

Leaf spot diseases of pulses and other crops caused by species of *Cercospora* and other allied fungi have also been studied.

Sugarcane Diseases

The diseases to which sugarcane is subject have received attention from very early times. The investigation on red-rot due to *Colletotrichum falcatum* has been helpful not only to workers in India but in several other countries as well. A better account of sugarcane smut than the one by Dr. Butler in 1908 has yet to be written.

As regards mosaic, a virus disease, known to be capable of causing great reduction in yield in some countries, it has been shown that in Northern India, which is the chief cane-growing

tract, natural spread is extremely slight except in some parts of the Punjab. The disease can be effectively controlled by rogueing and by selection of setts. Tonnage experiments repeated over a number of years with Co. 213 have conclusively shown that this widely grown cane, though susceptible to mosaic, is very tolerant, *i.e.*, even a very high percentage of mosaic in it is not capable of reducing the yield by more than ten to fifteen per cent, there being no significant differences in sucrose, brix, purity and glucose when compared with healthy canes of this variety. And this was the case in high mosaic infection of the experimental tonnage plot which is seldom to be met with in nature ; the losses occurring in practice, therefore, are far smaller. This work to some extent allays the apprehension that was felt regarding the loss of tonnage in sugarcane and deterioration in the juice due to mosaic disease. Similar experiments are now being conducted with other popular varieties. Losses in ' thick ' varieties seem to be comparatively greater.

From more fundamental point of view, the study of mosaic virus has been pursued in various directions and much information has been collected on physical and chemical properties of the mosaic virus. Chief points of interest are that (i) in some of the varieties the mosaic virus is not uniformly distributed throughout the cane. All the setts from a cane affected with mosaic do not give rise to mosaic plants, some are apparently healthy, free from any mosaic symptoms. Such " recovery " is greater when setts from basal and middle portions are planted. (ii) The mosaic virus is of a rather sensitive type being easily inactivated with comparatively low concentrations of alcohol, acids and toxic substances ; being unable to stand dilutions beyond 1 :100 ; having a very short storage life in *vitro*, mosaic leaf juice becoming non-infectious in one to two hours' time ; and having comparatively low thermal death point. (iii) The existence of more than one mosaic virus strains in India with a very wide range (40°-70°C.) of thermal death point of mosaic leaf juices of different varieties strongly suggests this hypothesis. (iv) P. O. J. 2878, a variety recognised all the world over as highly resistant to mosaic, has recently been found badly affected with mosaic at Cuttack, Lyallpur, and Gurdaspur. (v) Sugarcane mosaic virus easily infects maize and *jowar* and *vice versa*.

As to the nature of the mosaic virus a tentative theory of the association of a bacterial cyclostage with mosaic infection has been put forward. If confirmed this finding is sure to be of great importance to all workers on virus diseases.

As regards fungal and bacterial diseases, much fresh information has been gathered regarding the known diseases of red-rot, smut, top-rot, etc. Pineapple disease and red stripe have been found to

occur in India, and two new seedling diseases (*Pythium graminicolum* and *Helminthosporium halodes*) causing foot-rot and the bacterial "stinking-rot" (*Bacterium pyocyaneum*) have been described for the first time. Exhaustive studies in red-rot have revealed that there exist several physiologic forms of the causal organism, *Colletotrichum falcatum*, which though morphologically identical possess greatly varying degree of pathogenicity, the thick-cane strain being distinctly more virulent. All such important strains are included in the varietal test for red-rot resistance studies, and it has been found that Co. 281, 290, 299, 313, 331, 352, 354, 360, 362, 402, 411, 412, 413, 417, 419 and 421 are comparatively resistant. Co. 223 is the most susceptible of all the varieties tested.

Cross-inoculation with smut spores from thick and thin varieties collected from widely separated localities were equally successful, showing thereby the similarity of the organism in different localities. Experiments are in progress to find out the modes of infection, perennation, and comparative resistance of various cane varieties to smut.

Studies in sugarcane wilt (*Cephalosporium sacchari*) have revealed some differences from the original account of the disease, the chief being the absence of wilting of the entire cane in certain cases. This fungus also possesses several strains of different virulence.

"Pokkah-boeng" or top-rot (*Fusarium moniliforme*) disease, though recorded only recently in India, is gradually becoming more prevalent. Last year this disease was reported to be rather severe and wide-spread, particularly in Bihar and the Punjab.

Systematic studies of sugarcane wilt and the top-rot organisms have revealed that these two forms are really the two stages of the same fungus, but pathologically the two are quite distinct, as artificial inoculations with *F. moniliforme* stage of twenty-two cane varieties failed to give any successful infection of cane-stem.

Surveys have been carried out in various districts, and much information has been accumulated as to the susceptibility and resistance of different varieties of cane both to mosaic and to important fungal and bacterial diseases.

Smuts

Cereal and other smuts have received considerable attention. A new bunt, *Tilletia indica* Mitra, has been recorded on wheat in India. It has been found out that this bunt which occurs in regions at the foot of the hills in North-West India is both seed and soil-borne. Experiments on control measures are being tried and valuable results have been obtained.

A smut which causes root galls in mustard has been found to be new and named *Urocystis brassicae* Mundkur. A method recently developed to control oat smut has found wide application and appreciation. Studies of smut nomenclature, smut resistance and an attempt to bring out a monograph on India smuts, which are all on hand, will, it is hoped, add considerably to our knowledge of these destructive fungi.

Plantation crop Diseases

Diseases of rubber, tea and coffee have also received attention. While it has not been possible to do anything spectacular, for want of facilities, work on the pathogenic forms has been undertaken and done and much new information gathered. The diseases of cinchona have also been under investigation, and a seedling disease caused by *Phytophthora palmivora* has been recorded for the first time in India.

Fruit tree Diseases

In Kumaon and North-West Frontier Province a survey of fruit tree diseases was made and control measures were tried by spraying against diseases doing good deal of damage to important fruit trees. The fungicides tried gave encouraging results, especially against leaf-curl and mildew.

A similar survey of fruit tree diseases was made in Baluchistan and a paper was published for the guidance of other workers.

TYPE-CULTURES

A beginning has been made in the collection of type cultures. Judging from the requisitions for isolates of different fungi, the collection will prove useful to other workers in mycology.

REPORT OF THE IMPERIAL AGRICULTURIST

(ARJAN SINGH, ASSISTANT AGRICULTURIST)

INTRODUCTION

The Agricultural Section is one of the major departments of the Imperial Agricultural Research Institute. It consists of the main Agricultural Farm at New Delhi with the Statistical Branch of the Institute attached to it and the Agricultural Sub-station at Karnal. On both these stations cattle-breeding operations are carried on along with agricultural work. The Sahiwal breed is maintained at New Delhi and the Hariana and Tharparkar breeds at Karnal. The chief functions of the Section are to provide full facilities to other departments of the Institute for their research work in the fields, to test the results of their researches on field scale, to multiply seeds of improved varieties of crops produced by selection and breeding and to distribute them to Provincial Agricultural Departments and private individuals all over India. Agricultural experiments on different grain, fodder and revenue crops, manurial and cultural experiments, and testing of machinery and implements of all India importance are also carried out on a large scale.

1. AGRICULTURAL SECTION, NEW DELHI

I. ADMINISTRATION

Mr. Wynne Sayer held charge of the Section up to 27th May, 1937, when he proceeded on leave and Mr. Arjan Singh, Assistant Agriculturist, was placed in charge of the office of the Imperial Agriculturist in addition to his own duties.

II. TRAINING

Messrs. Mohamad Hussain, Syed Mudassir Ali and K. K. Khosla completed their one year's post-graduate course in farm organisation, farm management and general farm engineering. Messrs. Yashpal Chandra Gupta (U. P.), Nakibuzzaman Ahmed (Assam) and Fazal Karim (Punjab) were admitted in November 1936.

The following post-graduate students of the Imperial Dairy Institute, Bangalore, attended the short course in cattle management for two months :—

1. Mr. J. K. Makhijani (Sind).
2. Mr. R. Soundara Rajan (Madras).
3. Mr. M. C. Dutt (Assam).
4. Mr. Syed Kamal (N.-W. F. P.)
5. Mr. J. S. Francisco (Bombay).

The following staff were trained in milking and handling of cows :—

1. Mr. M. L. Dubey (In charge, Cattle Farm, Bharari, U. P.) received training for three months with one fieldman and nine herdsmen mentioned below :—

Fieldman

(*i*) Mr. Prem Sukh	Government Cattle Farm, Manjhara, Lakhimpur, Kheri.

Herdsmen

(*ii*) Panna Lal (*iii*) Puran (*iv*) Kundan	Government Cattle Farm, Bharari, Jhansi.
(*v*) Parmeshwar Din (*vi*) Itwari Goria (*vii*) Saheb Din	Government Cattle Farm, Manjhara, Kheri.
(*viii*) Bhagwanta (*ix*) Gajadhar (*x*) Karan Singh	Government Cattle Farm, Madhuri Kund, Muttra.

2. Bhimbahadur, Naik, No. 1400 L/NK, and

3. Tekbahadur, Rifleman, No. 1381 Rfn. of the 9th Gurkha Rifles, Dehra Dun, were given the above training for six months.

4. Mr. Zafar Ali, Veterinary Assistant, Lahore, Punjab, received training for one month.

III. FARM AND CULTIVATION

The work of the year under report is described briefly in the following pages. Most of the attention was devoted this year to the organisation and layout of the farm.

1. Work at Pusa

All experimental work was closed at Pusa except the permanent manurial and rotation experiments and the new manurial and rotation experiments which were carried on till they were transferred to the Superintendent, Botanical Sub-station there in the month of August. Necessary fodder crops were grown for feeding the livestock which stayed there till 15th October, 1936, the scheduled date for their departure to New Delhi. The transport of a large amount of goods from the Institute to Pusa Road Railway Station was done by the farm bullock carts with the help of permanent staff and labour.

2. Work at New Delhi

After successfully completing the move of the Institute from Pusa to New Delhi, the Assistant Agriculturist and the Imperial Agriculturist assumed charge of the Agricultural Section on 1st September and 19th October, 1936, respectively. The Layout Party was disbanded on 30th August, 1936. On joining duty, the whole staff was immediately engaged in putting into order the huge amount of store materials, plant, machinery and implements transferred from Pusa. The stock was verified and checked with the load lists and entered into new ledgers. Simultaneously, the agricultural work in the fields was earnestly taken in hand.

(*i*) *Situation of the Agricultural Section on the Institute.*—The Agricultural Section is situated on the west of the Institute. The P. W. D. road leading to Farm and Dairy divides it into two portions. The area on the south-east of the road contains all the farm buildings, cattle sheds and grazing grounds, and on the north-west side of the road are the agricultural lands.

The total area of the farm is 552 acres as detailed below :—

	Acres
1. Main block	291
2. Middle block	49
3. Sewage block	29
4. Top block	57
5. Farm buildings and cattle shed block	94
6. P. W. D. drains and main road	16
7. Bund	16

The farm is fenced all round with Ideal woven wire fence. The western boundary runs along an old bund which has also been acquired. The area of the bund is 16 acres. The net area available for crop growing and experiments, after allowing for buildings, roads, drains, water-courses and grazing grounds, is estimated to be 377 acres.

(*ii*) *Lay-out.*—The cultivable area is laid out into rectangular unit plots of 15 acres each (990′ × 660′ net) running parallel to the main P. W. D. road. On the top of each plot flows the water-course and at the bottom there is a drain ; on both ends there are roads. This size of plot has been found suitable for all purposes such as mechanical and bullock cultivation and economic irrigation. It can also be divided into any size of small uniform plots for experiments.

(*iii*) *Irrigation.*—The irrigation water is supplied by the Services Division, Central Public Works Department, in bulk from the Bholi Bhatyari reservoir at the rate of 0-2-3 per 1,000 gallons, and it is brought to the Institute end in a 24″ Hume pipe. From there, it is distributed into the fields through open channels. The size of the water-courses is capable of holding 2 to 3 cusecs of water. The

longitudinal slope is kept at 1 : 2000, limiting the velocity to only 1·4 ft. per second which is considered satisfactory to reduce silting of channels to the minimum for such soils.

(*iv*) *Drainage.*—There is a slope of about 25 ft. from the hillside boundary of the Institute down to the bund. The storm water which used to flow all over the Institute lands by natural *nullahs* has now been diverted by means of catchment drains into two big P. W. D. drains which run down through the farm land across the bund. Field-drains which run lengthwise below each plot deal with the water of individual plots and subsequently lead to these big P. W. D. drains.

(*v*) *Levelling.*—When I took over charge of the farm at Delhi, plot Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9 and Shadipur "A" in the main block making 148 acres were roughly levelled by the Layout Party. This area was not quite ready for proper irrigation. It was again finally levelled during the year, and a further area of 115·17 acres in the main block (Plot Nos. 10, 11, 12, 13, 14, 15, 16, 17 and Shadipur B and C) and about 14 acres in the sewage block were laid out and levelled. The top block of about 57 acres in area, which is extremely uneven owing to natural *nullahs* flowing through it, was ploughed twice with steam tackle to kill the jungle and scrub growths, and subsequently its layout was taken in hand. The natural drop in level between the main P. W. D. road leading to Farm Office and the bund is about 12 feet, and consequently a huge amount of earth had to be removed from high levels and put into the lower ones. As it was almost impossible to bring the individual plot into dead level within this short period, a slope of about 1 in 600 has been allowed to the width of the plot. To facilitate proper irrigation, each plot has been subdivided by temporary bunds which are removed at the time of cultivation.

(*vi*) *Soil.*—The soil of the farm is deep alluvial. It is either light sandy loam in many of the high plots or clayey in low-lying plots towards the bund. It is of a heterogeneous character containing patches of *kanker*, but there is no *reh*. From the experience of growing crops during the last *rabi* season, the soil seems to be well suited for agricultural work. As the land, when acquired, was full of jungle, except some cultivated patches round wells, it abounds in all sorts of weeds, especially *baru* (*Andropogon halepensis*), and *kans* (*Saccharum spontaneum*) which are deep-rooted and difficult to eradicate. By continuous cultivation and growing of crops, it is hoped to clear the fields of harmful weeds in course of time. Considerable time will be required to condition the soil before it is fit for any experiment.

(*vii*) *Crops.*—Although the land which was reclaimed and levelled during the last year was not fully ready and was only roughly

levelled, an effort was made to grow the following crops in order to test the irrigation system, to produce food and fodder for the livestock and to see the soil behaviour to various crops.

In addition to the crops mentioned in the statement below, the following 54 varieties of sugarcane, which were grown in the nursery plot at Pusa, were brought and planted here for multiplication of seed for further work on cane as was done at Pusa :—

Co. 210, Co. 213, Co. 281, Co. 299, Co. 313, Co. 331, Co. 344, Co. 347, Co. 348, Co. 366, Co. 368, Co. 370, Co. 371, Co. 374, Co. 377, Co. 378, Co. 381, Co. 382, Co. 384, Co. 386, Co. 391, Co. 394, Co. 413, Co. 417, Co. 419, Co. 421, Co. 423, Co. 424, Co. 425, Co. 426, Co. 427, Co. 428, Co. 429, Co. 430, Co. 431, Co. 432, Co. 433, Co. 434, Co. 500, Co. 501, Co. 502, Co. 503, Co. 504, Co. 505, Co. 506, Co. 507, Co. 508, Co. 509, Co. 510, Co. 511, Co. 512, Co. 513, Co. 514 and Co. 516.

Small quantities of Co. 213, Co. 331 and Co. 313 were imported from the Karnal Sugarcane Sub-station, and a half-acre plot was planted under Co. 213 from village seed for the Imperial Agricultural Chemist.

All varieties of sugarcane are growing excellently. Co. 213 grown from village seed is reported by the Plant Pathologist to be infested with smut disease. It is proposed to destroy this seed-cane as soon as the Imperial Agricultural Chemist's requirements are fulfilled.

The following varieties of sugarcane received from Coimbatore in March 1937, have been planted here for multiplication :—

Co. 441, Co. 442, Co. 443, Co. 444 and Co. 445.

From the statement of yield of crops, it will be seen that all, except peas, did very well. Gram was not irrigated at all and oats received two irrigations.

Statement of Crop Yields grown at New Delhi during Rabi 1936-37

Name of block	Plot No.	Crop and Variety	Area in acres	Yield in maunds* Total	Average per acre
Main Block .	9	Gram T. 58 .	15·00	213·30	14·22
,, ,, .	8	,, ,, .	15·00	240·30	16·02
,, ,, .	7	,, ,, .	15·00	259·78	17·32
,, .	Shadipur A	,, ,, .	5·75	73·85	12·84
,, .	10, 11 and 12.	Berseem green fodder.	39·25	24,289·93	618·85
,, ,, .	5	Oats B. S. I. . } Pea T. 14-1 . }	15·00	331·50 } 10·00 }	22·77
,, ,, .	4 and 3 .	Barley . .	6·50	82·50	12·69
,, ,, .	2	Oats B. S. I. .	12·50	299·25	23·94
,, ,, .	1	,, ,, .	15·00	281·75	18·78
,, ,, .	4	Pea T. 14-1 .	2·50	11·75	4·70

Statement of Crop Yields grown at New Delhi during Rabi 1936-37—contd.

Name of block	Plot No.	Crop and Variety	Area in acres	Yield in maunds* Total	Average per acre
Main Block .	3	Pea T. 14-1 .	12·25	248·75	20·31
,, ,, .	4	*Khesari* (*Lathyrus sativus*)	2·50	42·25	16·90
,, ,, .	4	Pea No. 1 .	0·32	3·05	9·53
,, ,, .	4	,, ,, 2 .	0·31	2·18	7·03
,, ,, .	4	,, ,, 3 .	0·31	1·58	5·10
,, ,, .	4	,, ,, 4 .	0·31	0·40	1·29
,, ,, .	4	,, ,, 5 .	0·31	0·95	3·06
,, ,, .	4	,, ,, 6 .	0·31	3·75	12·10
,, ,, .	4	,, ,, 7 .	0·31	2·33	7·52
,, ,, .	4	,, ,, 8 .	0·32	3·93	12·28
,, ,, .	2	Gram P. F. 3.	0·33	3·00	9·09
,, ,, .	2	,, ,, 6.	0·31	3·78	12·19
,, ,, .	2	,, ,, 11	0·31	3·50	11·29
,, ,, .	2	,, ,, 15	0·31	2·88	9·29
,, ,, .	2	,, ,, 17.	0·31	2·93	9·45
,, ,, .	2	,, T. 17 .	0·31	3·48	11·23
,, ,, .	2	,, T. 25 .	0·31	3·43	11·06
,, ,, .	2	,, T. 28 .	0·31	3·38	10·90
,, ,, .	3	Sunflower-green fodder.	1·00	135·58	135·58
Sewage area .	..	Barley . .	5·32	94·50	17·76
,, ,, .	..	Oats . .	1·25	32·50	26·00

* 1 maund = 82·3 lb.

IV. MACHINERY AND BUILDINGS

1. Machinery and Implements

The steam ploughing tackle worked satisfactorily throughout the year in reclaiming the rough farm land at New Delhi. It ploughed 489·55 acres in 599·50 hours at a cost of Rs. 5-8-3 per acre. The tackle was sent to Karnal in the month of June for doing heavy ploughing work in Plot No. 7 which was lately under *batai*.

Out of the medium size tractors, *i.e.*, Vicker, McCormick Deering, Lanz Bulldog and Marshall, the McCormick Deering and Lanz Bulldog proved very satisfactory in all respects. They have nearly finished their life and were used for very light work during the year. Vicker was too expensive in fuel consumption (kerosene oil) and the Marshall, though not much used, proved absolutely unsatisfactory due to defective lubricating pump.

The two W. D. 40 McCormick Deering crude-oil tractors, Nos. 1614 and 1612, which were purchased last year, worked at Karnal throughout the year under report. Both of them had trouble with their lubrication system, and it was worse with tractor No. 1614. The total number of working hours and fuel consumption are given below. The work done differed with different implements used behind the tractors.

Period	Total hours	Total fuel consumed	Consumption of fuel per hour
	Tractor No. 1614		
		Galls.	Galls.
1st six months	641·78	1224	1·91
Last six months	243·00	448	1·84
	Tractor No. 1612		
1st six months	765·50	1451	1·90
Last six months	318·00	621	1·95

The " Hanomag " 55 H. P., which was purchased in March 1937 along with John Deer 4-furrow tractor plough, is working very satisfactorily on crude oil. It has a self-starting arrangement and starts directly on crude oil. To date it has worked for 153 hours with an average consumption of 1·85 gallons of fuel per hour.

A Ramchandra Water Lift was installed on an irrigation well at New Delhi and another at the Agricultural Sub-station, Karnal, for trial.

The Hissar S. 3A plough sent by the Superintendent, Hissar Farm, and the Allan-Gandhi Baroda General Cultivator and Bullock Hoe sent by the Commissioner of Agriculture, Baroda State, were received for trial. The Hissar S. 3A plough is more difficult to work as compared with the standard Victory plough. The Baroda cultivator is a modified form of our *gallian* and is useful for interculture of crops sown in rows. Both these implements are being given a thorough test.

2. Buildings

All farm and cattle buildings consisting of general store rooms, seed godowns, workshop, main milk byre, calf-boxes, young and dry stock sheds, bull boxes, *bhusa* sheds, etc., the detailed designs of which were supplied by the Imperial Agriculturist, were constructed by the Central Public Works Department. All buildings, except the main cattle byre, were ready at the time of taking over charge in September 1936. This byre was also completed before the middle of October when the cattle herd arrived here. Cattle buildings have been sited more or less according to the Pusa plan. The milk byre provides accommodation for 68 head of cows arranged tail to tail. The width of stalls has been graded to suit the lengths of different animals. Fittings of the best modern type have been provided which include, *inter alia*, an automatic watering arrangement for individual animals and the overhead trolly feeding and dung removing arrangements. Attached to the milking byre are the dairy rooms including a small laboratory.

To facilitate supervision by the staff and immediate removal of newly born calves into the calf-boxes (constructed near the milking byre), the calving boxes have been provided in the milking byre compound. These buildings are so placed that the dairy area is reduced to the minimum.

V. CATTLE BREEDING

1. The Pedigree Sahiwal Herd

The whole herd consisting of 16 bulls, 67 cows, 30 bull-calves and 59 heifers was moved to New Delhi in the month of October by a special train which left Pusa Road on 15th and arrived at Delhi Sarai Rohilla on the morning of 19th October, 1936. The condition of the cattle after 5 days' train journey was remarkably good. The milk yield fell from 20 lb. to 15 lb. per cow per day, but rapidly improved. The average milk yield per cow per day for the year under report was 20·7 lb. as against 21·2 lb. in the previous year. The health of the herd remained excellent throughout the year except for one case of "black quarter" and a few cases of pneumonia.

Statement of Milk Yield for the Year 1936-37

Month	Total yield excluding stripping (lb.)	Average yield	No. of cows in milk and dry			
		Per cow per day (lb.)	Total number (milch herd only)	In milk	Dry	Percentage of cows in milk
1936						
July	22,235	20·5	68	35	33	51·5
August	21,207	20·1	67	34	33	50·7
September	20,052	20·9	67	32	35	47·8
October	18,689	18·3	68	33	35	48·5
November	19,182	19·4	70	33	37	47·1
December	20,332	19·5	73	34	39	46·6
1937						
January	19,037	20·2	72	30	42	41·7
February	16,208	20·7	72	28	44	38·9
March	17,926	20·6	73	28	45	38·3
April	17,836	22·0	73	27	46	37·0
May	22,180	22·4	74	32	42	43·2
June	25,903	24·0	75	36	39	48·0
Average for 1936-37		20·7	71	32	39	44·9
Average for 1935-36		21·2	58	30	28	51·5

The performance of some of the cows and heifers is seen from the statement below :—

Name and No.	Date of birth	No. of calvings	Milk yield (lb.)	Days in milk
Cows				
Chansuri 653	11-3-32	2	10,119	306
Lalmil 287	31-8-29	4	9,728	304
Atuly 480	22-11-23	8	9,012	304
Birengee 631	14-1-31	3	8,741	305
Amba 495	28-2-24	9	8,722	306
Lachmohni 644	10-9-31	2	7,837	304
Muraee 547	25-5-26	7	7,540	304
Heifers				
Biblota 324	4-5-33	1	7,574	304
Choki 681	11-3-33	1	6,769	304
Durdha 688	16-4-33	1	5,815	305
Biamba 674	10-12-32	1	5,780	306
Rajbiri 711	20-2-34	1	5,759	304
Charoochi 667	10-9-32	1	5,711	305
Cholbina 699	3-8-33	1	5,614	304
Naraee 705	22-12-33	1	5,602	304
Lakhati 703	9-12-33	1	5,330	304
Rajurki 710	12-2-34	1	5,117	304

Chansuri No. 653, which gave 10,119 lb. milk in 306 days (a record for this herd), is an early maturity cow and is giving over 50 lb. milk daily in her third lactation.

2. Calf Rearing

The special calf rearing experiments in relation to early maturity were continued. The percentage of mortality among the pail-fed calves was 5·1 against 1·6 in the previous year.

Percentage of mortality amongst pail-fed calves during the year 1936-37

Year	Births	Deaths	Mortality per cent
1935-36	61	1	1·6
1936-37	59	3	5·1

3. Early Maturity Experiments

The early maturity experiments were continued. Over 60 per cent of the milch herd (47 cows out of 78) are now from early maturity stock. This is attributed to the increased number of early maturity heifers coming into milk.

4. Sale of Cattle

Fifty animals were sold during the year as detailed below. Besides these six animals were sold at nominal price and four animals were sent to *pinjrapole*. On account of the keen interest taken by His Excellency the Viceroy in the improvement of the cattle of the country, numerous enquiries for the supply of pedigree stock were received.

Statement of cattle sold during the year 1936-37

Particulars	No.	Total price	Average	Average for 1935-36
		Rs.	Rs. A.	Rs. A.
Cows	10	1,065	106 8	127 12
Heifer	1	60	60 0	64 0
Young bulls	21	1,530	72 14	77 8
Steerlings	13	470	36 2	51 4
Bulls.	5	1,050	210 0	..
Total .	50	..	..	..

The following is the annual statement of the livestock as it stood on 30th June, 1937 :—

Annual statement of live-stock as it stood on the 30th June, 1937

Description of cattle	Number of animals from last year	Increase			Decrease				Total
		By birth	By transfer	By death	By transfer	By sale	Sent to pinjra-pole	Dis-posed of other-wise	
Bulls for breeding .	19	...	2	...	6	2	...	...	13
Bulls for sale . .	...	...	5	...	...	4	...	...	1
Cows—milch herd .	64	...	20	4	2	3	...	...	75
Cows for breeding .	3	...	...	...	...	...	2	...	1
Cows for sale . .	5	...	2	...	...	7	...	...	...
Cows at New area .	3	...	...	1	...	1	1	...	...
Young male stock in dairy	29	37	1	4	22	11	...	...	30
Young male stock for sale.	12	...	20	...	2	24	...	...	6
Young male stock at New Area.	1	...	1	...	...	1	1	...	...
Young female stock in dairy.	61	22	1	6	20	...	...	2	56
Young female stock for sale.	2	...	...	...	1	1	...	...	...
Young female stock at New Area.	2	...	...	...	...		...	...	...
Bullocks . . .	2	...	3	...	...		...	...	5
Total .	203	59	55	15	53	56	4	2	187

VI. PUBLICATIONS

The undermentioned papers were published during the year under report :—

1. Sayer, Wynne .	Early Maturity Experiments (First Report). *Agri. & Livestock in Ind.* **6**, 1936, 795-813.
2. ———— .	Feeding and Handling Experiments on the Pusa Pedigree Sahiwal Herd (Third Report). *Agri. & Livestock in India* **7**, 1937, 145-161.
3. ———— and Joseph, L. S.	Detoxicated urine Treatment for Impotency in Stud Bulls and Sterility in Cows. *Ind. Jour. of Vet. Sci.* **6**, 1936, 352-353.
4. ———— and Krishna Iyer, P. V.	On some factors that influence the error of Field Experiments with special reference to Sugarcane. *Ind. Jour. of Agri. Sci.* **6**, 1936, 917-929.

VII. PROGRAMME OF WORK FOR 1937-38

1. Layout and levelling of land and testing of soil in all plots.

2. Growing of fodder crops for cattle and the study of the rotations for building up the soil of the New Delhi Farm to a high level of fertility.

3. The study of irrigated and unirrigated crops on this soil.

4. Layout of permanent experimental plots and general experimental area.

5. Conduct of experiments for other Sections of the Institute.

6. Testing of sugarcane varieties received from Coimbatore.

7. Continuation of cattle-breeding operations on the pedigree Sahiwal herd with special reference to the transmission of milch characters.

8. Special feeding of the young stock with a view to early maturity in the Sahiwal herd.

9. Training of post-graduate students.

2. AGRICULTURAL SUB-STATION, KARNAL

I. RAINFALL AND CROP YIELDS

The total rainfall during the year under report amounted to 29·34 inches as against 40·61 inches in the corresponding period of the previous year, and 32·67 inches in 1934-35. The yields of principal crops grown on the farm are given in the table below :—

Statement of crop yields under direct cultivation

Crops	Area in acres	Yield in maunds* Total	Average per acre	Remarks
Maize corn	68·97	400·30	5·80	
Soybean	3·31	21·00	6·34	
Cowpeas	3·34	20·42	6·11	
Sunnhemp	0·42	5·30	12·62	
Meth	3·45	33·25	9·64	0·21 acre cut for green fodder.
Oats	385·60	6,246·20	16·20	47·52 acres damaged due to water-logging and 6·7 acres cut green.
Barley	18·68	240·12	12·85	
Wheat	58·94	972·17	16·49	
Gram	268·92	5,302·90	19·72	
Lentils	9·99	44·50	4·45	
Peas	0·41	7·90	19·27	
Berseem seed	0·89	2·94	3·30	
Berseem green fodder	10·50	8,555·50	814·81	* 1 md. = 82·3 lb.

II. FARM AND CULTIVATION

1. General

The total area of the Sub-station is about 2,154 acres, out of which 51·24 acres remained under the control of the Sugarcane Sub-station under the Sugarcane Expert. The area under direct cultivation of the farm was 817·97 acres, while 351·82 acres in Plot No. 7 were left under *batai* as the resources of the farm were not adequate to take whole of the area under direct cultivation.

As the major portion of the area under direct cultivation was taken over from *batai*, the fields were not fit for normal cultivation. An attempt was, however, made to put all the available land under some crop or other in order to keep down and exterminate weeds and grasses, and it is satisfactory to note that, although yield from this area was below average, the fields have now become cleaner than before.

Observations taken from the crops that were grown in *kharif* indicated that fodder crops like maize, soybean, *meth* (*Phaseolus*

aconitifolius), cowpeas and *guar* (*Cyamopsis psoralioides*) can be grown successfully at Karnal.

Amongst the crops grown in *rabi*, berseem as green fodder has proved a great success. An average outturn of 815 maunds per acre of green fodder under ordinary conditions of cultivation has revealed a new aspect for the improvement of the milch herds. An attempt was also made to procure berseem seed after third and fourth cuts of green fodder, and 2·94 maunds of seed have been obtained from an area of 0·89 acre. The results are very encouraging.

Besides the production of food and fodder for the herds at New Delhi and Karnal, the other activities of the farm were as follows :—

(*i*) Remodelling and laying out of fields to make them workable under mechanical cultivation.

(*ii*) Straightening of irrigation channels and construction of field roads to facilitate cultivation and supervision.

(*iii*) Seed multiplication of wheat P. 4, P. 111, P. 114, P. 120, P. 165 and P. 80-5 on an area of 50 acres for distribution.

2. Field Experiments

Full facilities were given to the under-mentioned officers for carrying out their field experiments at the Sub-station :—

(*i*) *Imperial Economic Botanist, New Delhi.*—About 30 acres of land was worked for plant culture and yield trials with different crops.

(*ii*) *Imperial Mycologist, New Delhi*, carried out his work on oats smut and wheat smut.

(*iii*) *Plant Pathologist, New Delhi*, conducted experiments on the effect of mosaic on the tonnage and juice of sugarcane E. K. 28.

(*iv*) *Statistician, New Delhi*, conducted an uniformity trial with wheat P. 114 for the determination of suitable plot size to be adopted in field experiments.

(*v*) *Plant Physiologist, Lyallpur*, carried out an yield trial with four varieties of cotton, *viz.*, Desi, 4F, 43F, and L. S. S.

3. Irrigation

The Sub-station receives its supply of irrigation water from the Western Jumna Canal on a rotation system depending upon the availability of water in the canal. The full supply of water is guranteed usually for 10 days in a month for irrigating 473 acres of land in *kharif* and 471 acres in *rabi*, whereas it is now contemplated to control 1,000 acres in *rabi* and 400 acres in *kharif*. This uncertainty of water supply may not affect the general crops much, but it certainly cannot meet all the requirements of the experimental

crops and experiments which have been started and are to be carried out in future. The failure in getting canal water for irrigating the wheat crop this year, when the canal was under repairs, resulted in the fall of its yield below the average. The necessity of providing a couple of tube wells at this stage on a farm like this cannot be overlooked.

4. Drainage

Drainage of rainwater from the farm area is a very important and big item. Ordinary cleaning of field drains was done during the year by the farm agency. A new drain along the railway line in Plot No. 5 West was dug out, and the earth was utilised for raising up the road running along the drain. The main project of the farm drainage has been taken up by the Central Public Works Department, and until this is done, no crop in Plot No. 6 and other low-lying fields can be successfully grown.

5. Buildings

All buildings remained under the charge of the Central Public Works Department. The old and dilapidated buildings have been condemned by the above department, and steps are being taken to demolish them. Proposals for new buildings in their place have been made in the next year's budget.

Three unit-type sheds sent from Pusa were erected at different places in the fields for storing *bhusa*. A bullock byre (unit-type shed) was also erected in Plot No. 4 for housing bullocks which have to work in the field during busy season.

Most of the culverts on farm roads were widened for bigger implements to be taken over them easily.

6. Seed Supply

The following seeds were supplied during the year under report :—

Crop	Variety	Quantity lb.
Wheat	P. 4	3,036·13
	P. 12	1,913·01
	P. 80-5	123·42
	P. 111	201·59
	P. 114	185·13
	P. 120	185·13
	P. 165	185·13
		5,829·54

III. CATTLE BREEDING

1. Pedigree Herds

Two pedigree herds, Tharparkar and Hariana, constitute the cattle-breeding side of the Sub-station. The herd of buffaloes previously maintained here was disposed of in June 1936.

2. Breeding Policy

As reported in the previous year, both herds have been drafted into families according to pedigree, type and performance, and a breeding programme has been laid down to bring in as quickly as possible the most desirable characteristics in each breed and thus build up really good milch herds. Particular attention was paid to the Tharparkar herd.

3. Milk Yield

The special handling and feeding of the Tharparkar cows was started from March 1936, and four-times milking from January 1937. The improvement in the milk yield over the whole herd is evident from the table given below :—

Statement showing milking average per cow per day in the Tharparkar herd

Months	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37
July . . .	10·2	12·7	15·1	14·9	14·4	12·5	16·8
August . .	9·8	13·5	15·1	14·9	14·7	15·0	16·6
Sptember . .	8·2	12·2	13·2	13·4	14·8	13·4	16·4
October . .	7·2	10·5	11·4	11·5	12·8	13·7	15·6
November . .	6·6	9·1	10·2	10·0	11·8	13·2	15·1
December . .	7·0	9·7	10·2	10·6	11·7	13·8	15·7
January . .	8·6	9·6	10·7	11·0	11·8	14·1	16·4
February . .	9·2	11·0	11·6	11·1	13·1	14·1	16·2
March . .	10·1	12·9	12·3	11·4	13·9	15·1	18·8
April . . .	11·0	14·5	12·7	11·8	13·4	15·0	19·5
May . . .	11·7	16·2	13·2	11·6	13·8	16·1	20·8
June . . .	11·7	15·8	13·6	11·8	13·0	16·4	20·4

In the table below, the average milk yield of cows which completed their full lactation during the year under report has been compared with those obtained in two previous years, and the progress made is clearly seen.

Average milk yield of cows which completed their full lactations during the last 3 years

Year	No. of cows	Average milk (lb.)	Average number of days in milk
1934-35	62	3,204	254·6
1935-36	57	3,838	283·0
1936-37	69	4,422	276·1

Records of six best cows of each breed which completed their lactations during the year with their previous best yields are given below :—

Records of six best cows which completed their lactation during the year

Name and No. of cow	Present lactation			Previous best lactation		
	No. of calvings	Milk yield	No. of days in milk	No. of calvings	Milk yield	No. of days in milk
		lb.			lb.	
Tharparkar						
Thandi 4 .	9	6,878	305	6	7,708	386
Tabiri 17 .	6	6,004	305	3	5,530	367
Kumari 36 .	4	9,655	305	3	8,734	313
Toti 39 .	4	7,027	305	1	5,049	348
Fahmi 65 .	2	6,139	305	1	3,642	342
Birji 67 .	2	6,672	305	1	4,531	305
Hariana						
Halki 18 .	6	6,079	305	3	4,426	303
Malika 19 .	5	6,680	292	4	6,705	354
Mithi 41 .	4	6,652	305	2	6,742	365
Muthri 48 .	3	6,503	305	1	5,178	375
Meori 52 .	3	6,597	305	1	3,740	334
Mata 68 .	2	6,605	305	1	4,655	307

4. Premilking and handling of cows and heifers

Fifty-four cows and 9 heifers of the Tharparkar herd and 46 cows and 11 heifers of the Hariana herd which calved during the year, were treated and milked before calving on the Pusa method. With the exception of a few cows and heifers, all responded to this treatment and no trouble was experienced before or after calving.

The experiments of special treatment and three times milking against ordinary treatment and two times milking are being carried out as desired by the Imperial Council of Agricultural Research.

5. Calf Rearing

There were 150 births during the year, and all calves were weaned at birth and reared according to the Pusa system. The percentage of mortality amongst pail-fed calves is seen from the table below. All calves are now weighed once a week, and their weights are recorded up to the age of one year.

Percentage of mortality amongst pail-fed calves during 1936-37

Herd	No. of calves reared	Deaths	Mortality per cent
Tharparkar	129	13	10·1
Hariana	122	9	7·4

6. Diseases

There were 36 deaths during the year from haemorrhagic septicaemia, black quarter, joint illness, Johnes' disease and other common ailments. The main cause of these deaths is the insanitary condition of the surroundings due to bad drainage of the place.

Preventive inoculation against rinderpest was carried out on 115 animals with goat virus by the staff of the Imperial Veterinary Research Institute, Muktesar.

7. Sale of Cattle

Six Tharparkar cows, five Hariana cows and two heifers of each breed were rejected and sold by auction. Fifteen young male stock were sold at their book values, and two Tharparkar bulls were sold at a nominal price of Rs. 15 each.

The annual statement of livestock is given in the table below.

Annual statement of livestock as it stood on the 30th June 1937

Description of cattle	Number of animals from last year	Increase		Decrease				Total
		By birth	By transfer	By death	By transfer	By sale	Sent to Pinjrapole	
Bulls—Tharparkar	6	...	2	1	1	...	...	6
Bulls Hariana	4	...	1	...	...	...	...	5
Cows—Tharparkar	89	...	19	7	...	6	3	92
Cows—Hariana	87	...	19	1	...	5	1	99
Young female stock—								
Tharparkar	65	42	...	9	19	2	...	77
Hariana	67	36	...	4	19	2	...	78
Young male stock—								
Tharparkar	40	35	...	6	3	7	...	59
Hariana	35	37	...	8	7	10	...	47
Total	393	150	41	36	49	32	4	463

IV. PROGRAMME OF WORK FOR 1937-38

1. Multiplication of different varieties of wheat for seed distribution.

2. Manurial experiments with paddy and other field experiments for different Sectional Officers of the Institute.

3. Line-breeding investigations on the pedigree herds.

4. Early maturity experiments on the breeding herd.

3. STATISTICAL BRANCH

(P. V. KRISHNA IYER, M.A.)

I. GROWTH STUDIES ON PADDY

The data regarding the growth studies on paddy Types 24, 31 and 52, collected by the Imperial Economic Botanist, were analysed. The details will be published by the Imperial Economic Botanist himself, but a brief summary of the statistical analysis is given below.

(*i*) *Distribution of tiller counts.*—The distribution of the final tiller counts as judged from Fisher's values of g_1 and g_2 could not be considered to be normal. The values of g_1 and g_2 for the various types studied are shown in the table below.

TABLE I

Description and year in which types were grown.	g_1	g_2
Type 24, 1934—1935	$0 \cdot 369 \pm 0 \cdot 109$	$-0 \cdot 277 \pm 0 \cdot 218$
Type 52, 1934—1935	$0 \cdot 562 \pm 0 \cdot 110$	$0 \cdot 607 \pm 0 \cdot 220$
Type 31, 1935—1936	$0 \cdot 923 \pm 0 \cdot 118$	$0 \cdot 808 \pm 0 \cdot 236$
Type 52, 1935—1936	$0 \cdot 765 \pm 0 \cdot 121$	$0 \cdot 511 \pm 0 \cdot 240$

(*ii*) *Tiller counts and rate of tillering week by week.*—New tillers continued to be formed in all the types up to the 11th or 12th week from the date of sowing. After this stage very few tillers were produced. In the case of Type 24 which had a very large number of tillers, a few tillers died in the four weeks that followed. The rate of tiller formation was not constant. It fluctuated considerably from week to week.

(*iii*) *Height of tillers produced in different weeks.*—For all the types, the differences between the heights of tillers formed in the first nine weeks were not statistically significant. The tillers produced after the ninth week were not so high as those of the preceding weeks. The behaviour of Type 52 was different in the two years in which it was studied.

(*iv*) *Average length of panicle.*—With the exception of Type 24 the panicle lengths of tillers of different weeks were almost the same. The differential nature of the three types in respect of panicle length was not in evidence in at least the first few weeks.

(*v*) *Average weight of panicle.*—For every type the average panicle weight from tillers produced in the first few weeks (*i.e.*, up to the 5th or 6th week) was almost the same. But among the types there was a striking difference Type 31 had the maximum average panicle weight. But the variation within this type was rather higher than the other types.

(*vi*) *Percentage of ear bearing tillers among the tillers formed in different weeks.*—This varied considerably with the type and climatic conditions. In the case of Type 31, the death rate was more in the initial and final stages, whereas in Type 24 it was high only in the final stage. In Type 52, it remained uniform, but the seasonal influence was marked. It may also be noted that all the surviving tillers bore ears.

(*vii*) *Percentage of sterile grains from tillers of different weeks.*—Sterility was definitly more in the case of tillers produced at a later stage. It continued to be more or less uniform up to approximately the eleventh week. In Types 24 and 31 the percentage of sterile grains was more than that of Type 52.

(*viii*) *Correlation studies.*—The correlation and regression coefficient between (1) length of panicle and height of tiller, (2) weight of panicle and height of tiller, (3) weight of panicle and length of panicle and (4) weights of panicles and number of tillers per plant were calculated. A brief comment on the correlation values has been made below.

(*a*) r *between length of panicle and height of tiller.*—There was a high correlation between tiller height and panicle length. The minimum value of r among the various types studied was 0·71. The values varied from type to type and year to year.

The regression coefficients also differed between types and years and, therefore, it would not be possible to make any exact prediction on the basis of previous years' experience. Type 24 had a greater regression coefficient than the other types, but this advantage was partly neutralised by the higher sterility of Type 24.

(*b*) r *between weight of panicle and height of tiller.*—Here again there was a high correlation between the two variates, but it varied with types and years. The regression coefficients of panicle weight on tiller height for Types 24, 31 and 52 were 0·04, 0·06, and 0·05 respectively. It will be seen that the value of b for type 24 was a minimum. In the previous section we have seen how Type 24 had a larger number of tillers. But now we find that aspect nullified owing to the lower value of b.

(*c*) r *between weight of panicle and length of panicle.*—The correlation as in the two previous cases was high here also, the minimum value being 0·84. The regression coefficient differed from type to type. It was a maximum for Type 31 and a minimum for Type 24.

(*d*) r *between total weight of panicle per plant and number of tillers per plant.*—The minimum value of r was 0·80. The difference between the correlation values of Types 24 and 52 was not significant.

The regression coefficient was a maximum for Type 31 and a minimum for Type 24, the values being 3·0 and 1·8 respectively. Here again it may be noted that Type 24 is inferior to the other types as judged from this point of view. But these drawbacks, as has already been mentioned, are offset by the production of a large number of tillers.

(*e*) *Partial and multiple correlations.*—The multiple correlation coefficients showed that the multiple regression lines were in no way an improvement over the simple regression lines, and therefore, no useful purpose will be served by using the multiple regression equations.

II. RESEARCH WORK

1. *Relation between Fisher's t and z for more than two samples.*—It is already known that Fisher's analysis of variance and t tests are identical when we are dealing with two samples. In the case of more than two samples it can be shown that the ratio of variances due to treatments and residual error is equal to the average of all the t^2's that can be formed.

2. *Distribution of the mean of Fisher's t^2's for samples belonging to a normal population.*—If there are a number of independent t 's, say n_1 in number, based on a common variance with n_2 degrees of freedom, it can be established that the distribution of the average of the t^2's is the same as that of the ratio of two variances based on n_1 and n_2 degrees of freedom.

3. *Relation between Hotelling's T^2 and Wilks' generalised variances.*—It has been observed that for two samples involving n variables a relation almost similar to the one between t and z exists in the case of T^2 and the ratio of generalised variances, *i.e.*, $\frac{|a_{ij}| - |c_{ij}|}{|c_{ij}|} = KT^2$, where K is a constant depending on the size of the samples.

4. *Size of samples for experimental purposes.*—The size of samples so that the mean and the standard deviation for different values of the coefficient of variation (from 1 to 12) lie within various limits of the population values for P= ·01 and P= ·05 has been worked out by using the P λ tables of Neyman and Pearson.

III. PUBLICATIONS

1. Krishna Iyer, P. V. — A note on the relation between Fisher's t and z. *Curr. Sci.* **5**, 1937, 473-474.

2. Krishna Iyer, P. V. — The distribution of the mean of Fisher's t^2 for samples from a normal population. *Proc. Ind. Aca. Sci.* **5**, 1937, 528-531.

3. Sayer, Wynne and Krishna Iyer, P. V. — Some factors that influence the error of field experiments with special reference to Sugarcane. *Ind. Jour. Agri. Sci.* **6**, 1937, 917-929.

REPORT OF THE IMPERIAL ECONOMIC BOTANIST

(B. P. PAL)

I. INTRODUCTION

With the transfer of the Imperial Agricultural Research Institute from Pusa to Delhi, the Botanical Section commenced its activities at the new site on September 1, 1936. As the levelling and laying out of the fields had not been completed and as water for irrigation was not available, no crops could be grown in the Botanical Area at New Delhi during the year under report. The continuity of the work of the Section was however not disturbed as arrangements were made for continuing the investigations at Pusa and Karnal respectively. For this purpose part of the staff of the Section was stationed temporarily at Pusa, and an Assistant was retained at Karnal.

The Section experienced an irreparable loss by the death on the 29th July of Dr. F. J. F. Shaw who had guided the Section since 1924 and was responsible for the progress it has made in recent years. His premature demise has been genuinely regretted by every individual member of the staff of the Section.

Dr. B. P. Pal remained in charge of the Section throughout the year and was appointed as Imperial Economic Botanist on April 5, 1937. The post of Second Economic Botanist previously held by Dr. Pal remained vacant from that date.

II. TRAINING

(*i*) *Post-graduate Training.*—Messrs. A. K. Mallik, S. D. Misra and R. K. Tandon completed their post-graduate training during the year and were of material help in the investigations with which they were concerned. Messrs. N. Alam, C. A. Joseph, G. Ranganathaswami and S. Sen continued to receive training.

Messrs. R. N. Das (Orissa), K. K. Khosla (Patiala), T. Narayana Rao (Madras) and S. Solomon (Bombay) were admitted this year. Mr. Das, however, left on April 12, 1937, to take up an appointment in his province.

The post-graduate students were at the Botanical Sub-station, Pusa, for the period January 1 to April 30, and at headquarters for the rest of the year.

(*ii*) *Short Course in Flue-curing of Tobacco.*—This course was held at the Botanical Sub-station, Pusa, and was attended by the following students :—

Ch. Nur Mohammad, Punjab Department of Agriculture.

Mr. R. M. Singh, U. P. Department of Agriculture.

Mr. V. S. Aiyenger, Madras Department of Agriculture.

Mr. G. T. Shahane, Institute of Plant Industry, Indore.

(*iii*) *Other Courses.*—Mr. P. M. Ganguli, Assistant, Assam Department of Agriculture, joined on April 1, 1937, for one year's training in plant breeding. Mr. Mirchandani, Oilseeds Assistant, Sind Department of Agriculture, was given facilities to study the linseed and safflower crops at Pusa from 5th to 15th January, 1937.

III. SUB-STATIONS

The following Sub-stations, financed by the Imperial Council of Agricultural Research, are under the direct control of this Section :—

(*i*) Botanical Sub-station, Pusa.

(*ii*) Potato Breeding Sub-station, Simla.

(*iii*) Tobacco Research Sub-station, Guntur.

(*iv*) Wheat Breeding Sub-station, Simla.

The work done at the Sub-stations during the year under report is given in detail in the respective reports on these Sub-stations submitted separately to the Imperial Council of Agricultural Research. The more important features of the reports are discussed under the appropriate heads in this report.

IV. LAY-OUT

When the Botanical Section took over from the Lay-out Party at the beginning of September 1936, only the rough levelling of the plots had been done. During the past nine months thirty-one plots received final levelling, leaving teventy-three plots to be completed during the coming *rabi* season.

The cultivable area attached to the Botanical Laboratories comprises about 50 acres laid out mostly in one-acre plots. All the plots have a natural slope from south to north, and to facilitate irrigation a gradient of about three inches in every hundred feet has been maintained.

During the hot weather the land was cultivated and left exposed to the sun and air. Farmyard manure was applied to those plots the final levelling of which had been completed, at the rate of about 250 cubic feet per acre. The remaining plots were roughly levelled and prepared for sowing sorghum.

V. SEASON AND RAINFALL

The Botanical Section used to maintain its own observatory at Pusa to record meteorological data. At Delhi, however, it is not intended to continue this practice, as the Section of Soil Science and Agricultural Chemistry will be maintaining detailed weather records.

As mentioned earlier, most of the experimental work of the Section was conducted at Pusa. There the total rainfall during the year was higher than the average, but the cold weather months were rather dry, with the result that low crop outturns were obtained from most of the *rabi* crops.

At Karnal the total precipitation during the year amounted to 29·34 inches as against 40·61 inches of the previous year. Monsoonish weather accompanied by storms and hail in the months of March caused considerable damage to *rabi* crops. The yields were consequently low and grain quality was poor.

VI. INVESTIGATIONS

As mentioned before, no crops could be grown at the Botanical Area at Delhi during the year under report and the experimental work of the Section was carried on at Pusa and Karnal. For this purpose part of the staff of the Section was temporarily stationed at both these places. Other officers of the Section were also frequently on tour to Pusa and Karnal to study the crops growing there.

WHEAT (*Triticum vulgare* Host.)

(*i*) *Bushel Weight.*—The year was an unfavourable one for wheat in respect of yield both at Pusa and Karnal. In the former place, however, the quality and plumpness of the grain of most strains was above the average. The bushel weights are given below for comparison with those recorded in previous years :—

Bushel weights of Pusa wheats in 1936-37

Variety	Weight per bushel in lb.			
	Average for the six years ending 1933-34	1934-35	1935-36	1936-37
Pusa 4	64·42	64·90	63·16	64·50
Pusa 12	62·39	62·60	54·52	62·95
Pusa 52	65·31	65·31	63·92	66·58
Pusa 80-5		64·50	64·85	65·30
Pusa 101		65·95	62·02	65·68
Pusa 111		63·50	63·38	63·60
Pusa 114			63·62	65·45
Pusa 120			61·72	63·35
Pusa 125			61·27	63·33
Pusa 165			61·79	65·10

(*ii*) *Yield Trials.*—Four sets of yield trials with wheat varieties were carried out at Karnal :—

(*a*) Yield trial of early-maturing hybrids from the cross Pusa 52 × Federation. This yield trial was a repetition of one carried out last year by the Botanical Sub-station. The results are summarised in Table I.

TABLE I

Summary of results of a yield trial with early varieties of wheat conducted at Karnal in 1936-37

Varieties	Mean grain yield in lb.							Standard Error of the Difference	Whether z test significant	Critical Difference for significance (P = 0·01)
	Pusa 80-5	Pusa 121	Pusa 122	Pusa 125	Pusa 126	Pusa 165	General Mean			
Yields Per acre	2,616·35	3 007·09	1,508·77	3,297·80	3,120·52	2,297·52	2,641·09	88·35	Significant	246·25
As a percentage of the General Mean.	99·02	111·43	55·91	122·21	111·93	97·87	100·00	...	...	...

Pusa 125 Pusa 126 Pusa 121 Pusa 165 Pusa 80-5 > Pusa 122

All the new hybrids except Pusa 122 were superior to the controls (Pusa 80-5 and Pusa 165) in yield.

(*b*) Yield trial of medium and late-maturing hybrids from the cross Pusa 52 × Federation. This yield trial was also a repetition of one carried out last year by the Botanical Sub-station.

The mean percentage yields (expressed as percentages of the general mean) were as follows :—

Pusa 114	Pusa 120	Pusa 121	Pusa 123	Pusa 124	Punj. 8-A	Punj. C518
70·28	71·07	120·32	101·38	109·12	120·75	107·02

As compared to the controls (Pusa 114 and Punjab 8-A), Pusa 121 and Pusa 124 gave satisfactory yields. Pusa 121 being a variety of medium maturity had also been included in the early series where likewise it had given good yields. The variety Punjab C518 also gave very high yields.

(*c*) New co-operative yield trials with Pusa wheats (U. P. series).

At the instance of the Agricultural Expert to the Imperial Council of Agricultural Research a new series of wheat yield trials was initiated at a number of Government Farms in the United Provinces, with the co-operation of the Director of Agriculture. The wheats Pusa 4, Pusa 12, Pusa 52, Pusa 80-5, Pusa 111, Pusa 120, Pusa 165, Cawnpore 13 and Punjab C518 are being compared in the present series. To secure uniformity in number of replications, etc., a standardised lay-out has been adopted. The results of these trials are not yet available.

(*d*) New co-operative yield trials with Pusa wheats (Punjab series).

A series similar to that described for the United Provinces has been initiated in the Punjab with the co-operation of the Director of Agriculture. The wheats being compared in this series are :— Pusa 12, Pusa 80-5, Pusa 114, Pusa 120, Pusa 125, Pusa 165, Punjab 8-A and Punjab C518. The results of the trials are not yet available.

One set of each series of yield trials was also laid down at Karnal for purposes of comparison. The results obtained will be considered together with those which will be received from the two Provinces concerned.

Both at Pusa and Karnal, the new wheat Pusa 125 (Plate III) has been the most successful among the Pusa wheats grown. Like Pusa 120, it has been bred from a cross between Pusa 52 and Federation, and while perhaps not so outstandingly rust-resistant as the former, it is superior to Pusa 120 in agronomic qualities. The further trials with this variety will therefore be watched with great interest.

(*iii*) *Breeding Work.*—Pusa 114 and Pusa 120 while otherwise excellent varieties have both a tendency to shed their grain when fully ripe. With the object of producing strains like Pusa 114 and Pusa 120 but without the defect of grain-shattering, a large number of progenies from " off-type " plants of these varieties were under study.

With regard to the work on the scheme for breeding rust-resistant wheats, the F_2 populations of eight crosses were tested for resistance in the green-house at Simla by Dr. Mehta and planted out in the field after the test. Observations were taken on the rust-resistance of the seedlings and at maturity plants were selected for carrying on to F_3 on the basis of rust-resistance and other desirable characters. Observations on certain morphological characters were also taken on these crosses with a view to correlate rust-resistance with some easily determinable morphological character,

PLATE III

Ears of Pusa 125 Wheat

thereby simplifying breeding for rust-resistance. Some early and medium-early crosses were also grown and studied at Pusa and Karnal.

The F_1 populations of a number of crosses, especially between Khapli and *vulgare* varieties, were studied. In most cases the seeds from such crosses either did not germinate or the plants died in the seedling stage. In one or two cases the plants produced ears which however were sterile.

Crosses between *T. Timopheevi* and *vulgare* varieties produced seeds which failed to germinate, while crosses between *T. Vavilovianum* and *T. vulgare*, *T. dicoccum* (Khapli) and *T. durum*, and *T. dicoccum* (Khapli) and *T. persicum* gave very vigorous hybrids.

Some new crosses were made in order to utilize Dr. Mehta's results on the adult resistance of certain varieties which were tested at Agra. A number of F_2 plants highly resistant to the three rusts were intercrossed with each other. The study of the hill and exotic varieties was continued.

(*iv*) *Genetical Studies.*—The study of the influence of certain external factors upon the manifestation of hybrid vigour in a cross between Pusa 52 and Pusa 165 was continued.

(*v*) *Registration of Wheat Varieties.*—At the instance of the Standing Wheat Committee of the Imperial Council of Agricultural Research, the Botanical Section has undertaken to maintain a register of (*a*) wheat varieties of commercial importance in India, and (*b*) wheat varieties likely to be of value for breeding work in India. In this connection nearly a hundred samples of wheat received from the Provinces and States were grown at Karnal and studied.

Barley (*Hordeum vulgare* L.)

The study of the inheritance of a number of qualitative and quantitative characters in crosses between *H. vulgare* and *H. distichon* L. was continued.

Breeding work with barley is being done by the Botanical Substation at Pusa.

Oats (*Avena sterilis* L. var. *culta* and *Avena* spp.)

Certain qualitative and quantitative characters were studied in the F_3 progenies of Orion × Pusa Hybrid J, and in the F_2 progenies of Lyallpur × B. S. 4 and P. F_2 × B. S. 4. The study of sterility in exotic oats was continued.

The resistance of Pusa oats to covered smut (*Ustilago kolleri*) is being studied with the collaboration of Dr. B. B. Mundkur of the Mycological Section, and details of the experiment will be found in the Report of the Imperial Mycologist.

Some new hybrids which are probably suitable for fodder purposes have been handed over to the Botanical Sub-station for trial at Pusa.

Paddy (*Oryza sativa* L.)

Pusa paddy types 18, 97, 130, 137 and 164 were again compared for yielding capacity at Karnal. The mean yields (expressed as percentages of the general mean) were as follows :—

T. 18	T. 97	T. 125	T. 130	T. 137	T. 164
96·42	75·77	101·56	104·70	98·64	122·84

Thus T. 125, T. 130 and T. 164 again proved superior to the varieties used as controls (T. 18 and T. 97).

The data on the tillering study mentioned in previous reports were analysed with the help of the Statistician. The results showed that new tillers continued to be formed in the three strains studied (T. 24, T. 31 and T. 52) up to the 11th or 12th week from the date of sowing. After this stage very few tillers were formed. The rate of tiller formation fluctuated considerably from week to week.

For all the types the differences between the heights of tillers formed in the first nine weeks were not statistically significant ; the tillers produced after the ninth week were not so tall as those of the preceding weeks. In average length and average weight of panicles there was not much difference, at least for the first few weeks.

The percentage of panicle-bearing tillers formed in different weeks varied considerably with the strain and the climatic conditions. In the case of T. 31 the death rate was higher in the initial and final stages, whereas in T. 24 it was high only in the final stages. In T. 52 it remained uniform, but the seasonal influence was marked. All the surviving tillers bore panicles. As regards the percentage of sterile grains from tillers of different weeks, sterility was definitely more in the case of tillers produced at a later stage.

Correlation studies were also made and the results are referred to in the Report of the Statistician.

Maize (*Zea Mays* L.)

Breeding and genetic investigations on maize were continued. Four inbred ears from each of the forty-four cultures referred to in the previous report were selected for planting this year. About seventy-five kernels from each of these ears were sown and about

one-half of the progeny was artificially self-fertilised. A large number of ears have been selected for further work on the basis of ear size, shape, grain quality, etc.

Eight American varieties of maize, namely, Woodburn's White Dent, Reid's Yellow Dent, Lancaster Sure Crop, Leaming Corn, Canada Leaming, Oswego Ensilage, Cornell 11 and Westbranch Sweepstake were grown, and a few plants from each were self-fertilised in order to produce inbred strains. The first three varieties were received through the courtesy of Prof. C. R. Burnham of West Virginia University Agricultural Experiment Station and the rest originally came from the Department of Plant Breeding of Cornell University.

On being self-fertilised, these varieties showed segregation in respect of seed colour, seedling and mature plant characters, etc., and a large number of mutant types which remain concealed under conditions of commercial crop production was revealed. A series of endosperm colours, *viz.*, orange, light orange, yellow, lemon, light lemon, dirty white, pearly and chalky white, and aleurone colours, *viz.*, red and purple, and pericarp colours, *viz.*, red and light red or brown was obtained. Nineteen stocks segregated for defective endosperm characters. Among the seedling characters light green, yellowish green, yellow seedlings, white seedlings, virescent, glossy and striped seedlings were most abundant. Two cultures segregated for dwarf plants, and two for zebra and golden plants. As regards mature plant characters many of the cultures segregated for male sterility, a few for salmon silk colour, two for dead margins of leaves, one for tassel seed, one for slashed plant and another for tasselless plants.

In order to ascertain whether or not some of the phenotypically similar forms were allelomorphic, crosses between the different stocks segregating for defective endosperm were made. Five glossies from different cultures were inter-crossed and the F_1 results indicate that they are all different.

Studies on the inheritance and linkage relations of zig-zag culms—3 and dwarf—7 types of maize were continued. A new virescent seedling tentatively called Virescent 21 (V_{21}) was also studied.

Linseed (*Linum usitatissimum* L.)

The F_1 and F_2 generations of a cross between Pusa Type 15 and Tamme's " crimped " were successfully grown in one year. Both the parents possess white petals but the F_1 had blue petals, indicating the presence of the factor C in Type 15. The F_2 frequencies showed that three factors are concerned in petal colour production in this case.

The F_2 generation of the cross between Pusa Type 12 and the yellow-tipped mutant from it (mentioned in last year's report) showed simple segregation of normal green and yellow-tipped plants in the ratio of 3 : 1.

A number of rust-resistant cultures derived from crosses between indigenous rust-susceptible varieties and foreign rust-resistant varieties were grown both at Pusa and Karnal. Further selections were made with the object of securing strains linking rust-resistance with other economically desirable characters, the selection being facilitated by the considerable incidence of rust.

Seven hybrids—H. 10, H. 13, H. 21, H. 55, H. 65, H. 68 and H. 69—were compared for yield against the standard variety, Type 12. The results show that the latter is superior to all the hybrids except H. 68 and H. 69.

Safflower (*Carthamus tinctorius* L.)

Genetical studies on this crop plant were continued. The F_2 generations of the crosses, Type 1 × Type 6, Type 1 × Type 30 and Type 6 × Type 30, were again grown and studied. A large number of plants from different phenotypes were selfed for carrying on to F_3.

Oleiferous Brassicae (*Brassica* spp.)

All the Pusa types of *B. campestris* var. *sarson* and var. *napus*, *B. juncea*, *B. alba*, *B. nigra* and *Eruca sativa* (*taramira*) were grown this year. Plants of each type were bagged ; from the amount of seed-setting a very good idea of the extent of self-sterility prevailing in various species was obtained. All the types of *toria* set very poorly under bag. The yellow-seeded *sarson* types are mostly self-fertile and set well. The types of brown-seeded *sarson*, except those which have been produced at Pusa by hybridizing brown-seeded *sarson* with yellow-seeded *sarson*, and Burma *sarson* (B. *campestris* subsp. *chinensis*), proved largely to be self-sterile. A number of types of *rai* (*B. alba*) and all the types of *B. nigra* were found to be self-sterile.

Crosses were made to investigate the problem of self-sterility in *B. campestris*. The inheritance of certain other characters such as flower colour, presence of anthocyanin, glossiness, seed colour, hairiness, etc., will also be studied. The biology of the *sarson* flower was studied and observations on the amount of natural crossing were made. Breeding work with *toria* was commenced.

PIGEON-PEA (*Cajanus Cajan* (L.) Millsp.)

The genetical investigation of this crop was continued on the lines described in last year's report. The F_1 generations of a cross between Type 51 and Type 24 and its reciprocal were grown and studied during the year under report. Type 51 is a wilt-resistant pigeon-pea with large, yellowish-brown seeds, while Type 24 is susceptible to wilt and has medium-sized, greyish fawn seeds. This cross was made with the object of combining in one strain the large seed size and wilt-resistance of Type 51 with the high-yielding capacity of Type 24, and also incidentally to study the inheritance of wilt-resistance and its possible correlation with certain morphological characters. As the climate of Pusa is better suited for work on this crop than that of Delhi, this investigation as well as other breeding work will be carried out by the Botanical Sub-station at Pusa.

GRAM (*Cicer arietinum* L.)

The study of inheritance of seed characters which was commenced by the Botanical Sub-station before its transfer to Pusa, was continued at Karnal by the Botanical Section. The F_2, F_3 and F_4 generations of a number of crosses were grown in this connection. The mode of inheritance appears to be complex, but it was not possible to draw any definite conclusion as heavy mortaily occasioned by *Rhizoctonia* wilt greatly diminished the size of the populations.

The study of the gram mutants (described in previous Reports of the Botanical Sub-station, Karnal) was also pursued. The mutant with very narrow leaves is breeding true but the behaviour of the simple-leaved mutant is rather complex. With the object of elucidating this, some plants of the latter have been crossed with Type 17, *i.e.*, the variety from which the mutant originated, and the progenies are under study.

PEAS (*Pisum sativum* L. and *P. arvense* L.)

The yield trial of three strains of *P. sativum* (S. 3, S. 16 and S. 29) and two strains of *P. arvense* (A. 8 and A. 15) was repeated. As in the previous year, the differences in yield between the varieties were found to be not statistically significant.

The collection of types of both the species was grown.

SUNN-HEMP (*Crotalaria juncea* L.)

The twenty-two cultures of sunn-hemp obtained by mass selection have been handed over to the Botanical Sub-station, Pusa, for final trials. The complex experiment designed to obtain

information regarding the best varieties, the correct seed-rate and the best time of sowing the crop for fibre purposes which was laid down last year at Pusa by the Botanical Section is also being continued by the Botanical Sub-station.

HIBISCUS (*Hibiscus sabdariffa* L. and *H. cannabinus* L.)

Samples of fibre of the New Hibiscus and of a fixed hybrid between the former and the variety *albus* of *H. sabdariffa*, grown and retted under identical conditions, were submitted to the Assistant Fibre Expert, Bengal, for comparative tests. The fibre of the hybrid was reported to be superior to that of the New Hibiscus in fineness and appearance.

TOBACCO (*Nicotiana tabacum* L. and *N. rustica* L.)

The work on flue-curing of tobacco has been taken over by the Botanical Sub-station, Pusa, pending the carrying out of experiments to see whether cigarette tobaccos can be successfully grown and cured at Delhi.

A five-year scheme for tobacco research was sanctioned by the Imperial Council of Agricultural Research, and the work was commenced in August 1936 at Guntur.

The study of the leaf-curl disease, which is one of the objects of the scheme, was carried out at Pusa instead of at Guntur as the disease is very serious in Northern India. The incidence of leaf-curl was studied by making monthly sowings of the variety Pusa H 142 throughout the year and aking weekly counts of the diseased plants. The results indicate that although the incidence of the disease occurs in various degrees throughout the year, it is heaviest in October. The results of experiments carried out by the Entomological and Mycological Sections will be found in the Reports on these Sections.

POTATO (*Solanum tuberosum* L.)

The major portion of the work on this crop is being carried out at he Potato Breeding Sub-station at Simla* where conditions are more suitable both for growth and for storage. The Station received thirty-one varieties, European and local, during the year. A few hybrids received from foreign countries gave very good yields, while others exhibited a high degree of resistance to Late Blight. A large number of crosses between these and some of the best Indian varieties were made successfully. Crosses using *S. demissum* as the female parent and *S. tuberosum* as the male parent were much more successful than the reciprocal crosses. A few intervarietal crosses were also made.

* Financed by the Imperial Council of Agricultural Research.

The study of flowering, pollen fertility and berry production which was commenced last year was continued. A few plants of each species were grown under " short day " (9 hours day light) conditions by covering them with dark covers. These plants were in no way superior in yield to those grown under normal day light in pots and boxes, while flower and berry production was decidedly less than that of plants growing in the field under normal conditions.

Late Blight appeared in an epidemic form during the year under report and afforded an opportunity for detailed observations on the relative resistance of wild and cultivated varieties growing at the Substation. In general the varieties of *S. tuberosum* were highly susceptible. Slight resistance was shown by varieties Pusa White, Coonoor White, Khabrar, Garhwal and Darjeeling Red, and moderate resistance by President. Six of the 124 varieties of *S. tuberosum* from South America showed a high degree of resistance. Most of the varieties of *S. andigenum* were highly stem resistant. Very few tubers of this species rotted. The variety Imperia appeared particularly susceptible to Early Blight. General notes on virus diseases were also kept.

Chilli (*Capsicum annuum* L. and *C. frutescens* L.)

Only a small population of the progeny of the natural interspecies cross between *C. annuum* and *C. frutescens* referred to in the last report was available for study. Segregation for flower colour (green or white), colour of unripe fruit (green or creamy), fruit position (erect or pendent) and number of pedicels in an axil (single or clustered) was noted. A large quantity of seed from the original hybrid plant has been collected, and it is hoped to grow a much larger population next year in order to study more closely the inheritance of the characters just mentioned.

The collection of 52 types was grown. Many of them were affected with " Leaf-curl " and some were also attacked by *Choanophora*. Type 41 was badly affected by the latter.

Other crops

The crop collections of sesaamum (*Sesamum orientale* L.), lentils *Lens esculenta* Moench), black gram (*Phaseolus Mungo* L. var. Roxburghii), green gram (*P. aureus* Roxb.) and Indian hemp (*Cannabis sativa* L.) were maintained, and routine work on these crops was continued.

Samples of cotton, sorghum and soybeans for preliminary studies were obtained from various parts of India through the courtesy of the Directors of Agriculture and of the specialists working on these crops in the Provinces.

VII. CROP OUTTURNS AND SEED DISTRIBUTION

The crop outturns for the Botanical Area at Karnal are given in the statement below :—

STATEMENT SHOWING THE YIELD OF CROPS IN THE BOTANICAL AREA AT KARNAL IN 1936-37

Crop and variety	Plot Nos.	Area in acres	Outturn of grain in lb.	
			Actual	Per acre
Experimental Area				
Wheat—				
Pusa 4	2 and 16	0·16	380	2,375
Pusa 12	,,	0·25	422	1,688
Pusa 80-5	,,	0·25	411	1,644
Pusa 111	,,	0·26	434	1,669
Pusa 114	,,	0·26	403	1,550
Pusa 120	,,	0·27	389	1,441
Pusa 165	,,	0·28	454	1,621
Peas—				
S. 29	3	0·33	164	497
*Flax *—*				
J. W. S. (Karnal seed)	1	0·39	261	842
J. W. S. (Dacca seed)	1	0·27	171	633
Liral Monarch	1	0·27	164	607
Paddy Area				
Rice—				
T. 18	2, 3, 4D	1·47	2,170	1,476
T. 97	1-4A	1·05	1,697	1,616
T. 125	1-3B, 1-3C	1·49	2,921	1,960
T. 130	5C, 5D	0·75	1,736	2,315
T. 137	6A-6D	1·06	1,974	1,862

* Grown for the Assistant Fibre Expert, Bengal.

Statement showing distribution of seeds from Botanical Sub-Station, Pusa

	Lb.	oz.
Wheat—		
P. 4	1,657	0
P. 12	186	0
P. 52	5,139	0
P. 80-5	38	0
P. 101	136	0
P. 111	444	0
P. 114	116	0
P. 120	65	0
P. 165	209	0
P. 122	21	0
Hy. N (125)	129	0
Barley—		
T. 21	4,029	0
Oats—		
B. S. 1.	360	0
B. S. 2.	195	0
Hy. C	506	0
Hy. G	167	0
Hy. J	33	0
Hy. 7-54	2	0
Maize	2,469	0
Paddy—		
T. 18	84	0
T. 9	4	0
T. 24	167	0
T. 31	82	0
T. 52	84	0
T. 89	82	0
Gram—		
T. 2	30	0
T. 6	25	0
T. 17	851	0
T. 25	495	0
T. 28	168	0
T. 53	165	0
T. 58	312	0
Rahar—		
T. 5	1	0
T. 15	60	0
T. 24	199	0
T. 51	817	0
T. 64	10	0
T. 69	10	0
T. 80	208	0
T. 82	28	0
Peas—		
S. 29	673	0
A. 15	8	0
A. 16	8	0

	Lb.	oz.
Mung—		
T. 18	4	0
T. 23	4	0
T. 28	5	0
T. 31	2	0
T. 36	48	0
Urid—		
T. 17	5	0
Lentils—		
T. 11	2	0
T. III-86	218	0
Soybeans—		
Black	14	0
White	292	0
Chocolate	14	0
Meth	218	0
Linseed—		
T. 12	163	0
T. 121	111	0
T. 124	441	0
Hy. 10.	14	0
Hy. 21.	5	0
Hy. 55.	34	0
Hy. 65.	5	0
Hy. 68.	74	0
Sesamum—		
T. 29	0	2
Safflower—		
T. 30	8	0
Patwa—		
T. 3	1	0
T. 6	12	0
New	20	0
Sunn-hemp	123	0
Chillies—		
T. 6	0	1
T. 46	0	7
T. 34	5	1
T. 41	0	1
T. 51	0	13
Tobacco—		
Hy. 142	7	1
T. 28	5	2
T. 18	2	0
Hy. 177	2	9
T. 63	0	6
T. 58	0	2
Harrison Special	4	11
Adcock	5	9
Cash	0	2

VIII. MISCELLANEOUS

(*i*) *Advisory Work.*—As usual a large number of enquiries were received from correspondents regarding varieties, methods of cultivation, curing, etc., and the information required was supplied.

(*ii*) *Monthly Discussion Meetings.*—A system of monthly meetings of members of the staff and students was initiated during the year to discuss the research in progress, current literature, etc. The meetings have been a success and every paper has been followed by a full discussion. Among the subjects were : Hybrid Vigour in Plants, The Improvement of Indian Oilseeds, The Classification of the Oleiferous Indian Brassicae, Methods of Inducing Mutations, Haploids and Polyploids, etc.

(*iii*) *Receipts.*—A sum of Rs. 1,940-4-3 (Rupees one thousand, nine hundred and forty, annas four and pies three only) was realized from the sale of improved seeds, etc., during the financial year ending March 31, 1937, and was credited to Government.

IX. PUBLICATIONS

PAPERS PUBLISHED DURING 1936-37

1. Bose, R. D. . . . List of Publications on the Botany of Indian Crops, Part II. *Imperial Council of Agricultural Research* Miscell. Bull. No. 12, 1936, p. 198.

2. Bose, R. D., Aziz, M. A. and Bhatnagar, M. P. Studies in Indian Fibre Plants. No. 4 : The Root-System of Sunnhemp (*Crotalaria juncea* L.). *Ind. Jour. Agri. Sci.*, 1936 : 6 : 351-60.

3. ———— , ———— and ————. Studies in Indian Barleys, 4. The Inheritance of some Anatomical Characters responsible for Lodging and of some Earhead characters in an Interspecific Cross between Two Pusa Barleys. *Ind. Jour. Agri. Sci.*, 1937 : 7 : 48-88.

4. Deshpande, R. B. . Mendelian Segregation in *Hibiscus sabdariffa* L. in relation to the Age of the F_1 at Time of Fertilization. *Ind. Jour. Agri. Sci.*, 1936 : 6 : 1274-91.

5. Ekbote, R. B. . . Mutations in Gram.
Curr. Sci., 1937 : 5 : 648-49.

6. Kashi Ram and Ekbote, R. B. The Classification of the Autumn Rices of the Punjab and Western United Provinces.
Ind. Jour. Agri. Sci., 1936 : 6 : 930-37.

7. Pal, B. P. . . A Note on the Relation between the Internal Stem Structure of Certain Varieties of Gram (*Cicer arietinum* L.) and their Resistance to Cutworm Attack.
Proc. Ind. Acad. Sci., 1936 : 3 : 527-34.

8. Pal, B. P. and Nath, P. A Note on the Sterile Hybrid between *Nicotiana Tabacum* L. and *N. plumbaginifolia* Viv.
Ind. Jour. Agri. Sci., 1936 : 6 : 828-32.

9. Purewal, S. S. and Krishna Rao, P. Tables of Standard Errors of Mendelian Ratios.
Imperial Council of Agricultural Research Miscell. Bull. No. 11, 1936, p. 37.

10. Shaw, F. J. F. . Studies in Indian Pulses. The Inheritance of Morphological Characters and Wilt-Resistance in Rahar (*Cajanus indicus* spreng).
Ind. Jour. Agri. Sci., 1936 : 6 : 139-87.

11. ———————— . A Handbook of Statistics for Use in Plant Breeding and Agricultural Problems.
Publ. by Imperial Council of Agricultural Research, India. 1936, p. 179.

12. Singh, H. and Ekbote, R. B. Inheritance of Seed Characters in Gram (*Cicer arietinum* L.).
Ind. Jour. Agri. Sci., 1936 : 6 : 1087-1104.

X. PROGRAMME OF WORK FOR 1937-38

The transfer of the Imperial Agricultural Research Institute marks a new epoch in the history of the Botanical Section. In view of the advances in plant breeding made in recent years in the Provinces, the Section will henceforward concentrate on advanced genetical work and such breeding problems as are best handled by a well-equipped and well-staffed central research institute. As soon as funds become available, it is also hoped to undertake cytological and physiological work on the important Indian crop plants. The programme of work for 1937-38 is as follows :—

(*i*) Continuation of the plant breeding work on the various crops which have formed the subject of this Report with the object of completing the work in hand so that new work on the lines indicated above may be commenced as early as possible.

(*ii*) Continuation and extension of genetical investigations on important Indian crop plants. Particular attention will be paid to the inheritance of disease resistance, and of the quantitative characters.

(*iii*) Study of heterosis.

(*iv*) Study of self-sterility in the oleiferous Brassicae with the object of improving methods of breeding self-sterile varieties of crops.

(*v*) Maintenance of crop collections.

(*vi*) Training of post-graduate students.

REPORT OF THE SUGARCANE EXPERT.

T. S. VENKATRAMAN.

I. GENERAL

The electrification of the station was completed during the year, and the Hon'ble Kunwar Sir Jagdish Prasad, Member of the Council of the Governor-General of India in charge of the Department of Education, Health and Lands, very kindly switched on the current on the 15th of January 1937. The work at the laboratories has considerably benefited from this change as also the water pumping facilities at the station.

II. SUGARCANE BREEDING (MAINLY SUB-TROPICAL TYPES) *

1. SUGARCANE × BAMBOO HYBRIDS

It is an accepted fact that success in sugarcane breeding depends largely on the extent of variation that could be secured in the seedlings raised. One method for extending the range of such variations is the employment of new parents. Both India and Java have, in the past, materially benefited from the introduction of the wild type, *Saccharum spontaneum*, as parent, and certain of the most popular of both the Coimbatore and Java productions have in them the blood of *S. spontaneum* in varying degrees.

In the year 1930 success was obtained in crossing the sugarcane with sorghum, and this has since been successfully repeated in other experiment stations of the world. The object in effecting the above cross was the production of short-duration canes. While a few such sorghum hybrids have been obtained, many of them show a lack of vegetative vigour, or, in other words, tonnage per acre. To remedy this defect various grasses, irrespective of their taxonomic position, were crossed with the sugarcane. It was felt that the present taxonomic arrangement—based as it is mainly on morphological characters—might not truly represent their genetic relationships.

Of these, crosses between two Java canes—P. O. J. 213 and P. O. J. 2725—and the bamboo (*Bambusa arundinacea* Willd.) gave successful germination. Most of these hybrids display greater vegetative vigour than the sugarcane parents. As is the case in F_1 generation plants with sugarcane as the ovule parent, this batch of seedlings shows considerable variations among themselves and

* The breeding of tropical types is detailed in the Report of the Second Cane Breeding Officer (Section V).

different bamboo characters are revealing themselves in different plants (Plate IV). Only twenty-nine hybrids were obtained during the current season as the bamboo pollen became available towards the fag end of the arrowing season for canes at Coimbatore.

It is not possible at this stage to foresee the economical results that may follow from this very wide cross. It is the ambition of the station to ultimately build up, if possible, sugarcane hybrids which would possess the blood of both sorghum for short duration and the bamboo for growth vigour. On the purely scientific side a fairly wide gulf might be said to have been bridged by the above hybridization.

2. 'Early' and 'late' canes

Mention was made in the last report of certain 'early' types which were distributed to experiment stations. The current year's results show that some of these are likely to be of use.

One of the difficulties in the growing of a 'late' cane under sub-tropical conditions is the prevailing summer heat which causes the canes to deteriorate and develop more fibre. One of the present 'late' canes, Co. 331, is reported to behave thus in parts of the United Provinces. A cross made during the year between sugarcane and *S. arundinaceum*—a perennial used as a hedge round betel-vine plantations—is showing promise in this direction. This hybrid, which is now over 24 months old, is behaving like a perennial producing new canes at each growing season and with the first formed canes not yet showing appreciable signs of deterioration. This line of hybrids will need, however, to be further 'nobilised' for sugar.

3. Parents

Two types of *S. spontaneum* obtained from mid-Asia through the courtesy of the Lenin Academy of Agricultural Sciences, U. S. S. R., have been fully established. These are expected to be of special use in the breeding of frost-resistant types. *S. robustum* successfully employed as parent during this season has not yielded any canes of marked vigour. The Burma *S. spontaneum* has yielded a very satisfactory type from the growth and habit view points for use as parent. The Co. cane parents appreciatively mentioned in the last report are continuing to show their usefulness in the directions mentioned.

4. Routine breeding programme

The breeding programme during the year included twenty-six combinations, nine of which were intended for out-stations like

Karnal, Mushari and Shahjahanpur. Over 200,000 seedlings were raised, 15,000 planted in the second ground nurseries, and about 400 of these selected for further trials. The area under canes is on the increase, and one direction in which an improvement is needed is the source of water supply. At present the whole crop is dependant upon one well—the only non-saline well at the station.

III. CYTO-GENETIC STUDIES *

In the previous report reference was made to the raising of hybrids under proper control and between parents whose genetical ' make up ' was known, as an essential for proper cyto-genetic work in the *Saccharums*. During the current year certain such hybrids as also selfed seedlings of interesting types became available as the result of work during the preceding two seasons. The more important of the results are mentioned below.

Polyploidy.—The further analyses of selfed seedlings of Co. 205 and its back crosses with *S. spontaneum*, as well as the hybrids between Kassoer and *Glagah*, clearly show the occurrence of polyploid inheritance in certain interspecific *Saccharum* hybrids.

The occurrence of giant forms, triploids in selfed seedlings of certain *S. spontaneums*, has helped to bridge the gulf between the wild *S. spontaneums* and Indian indigenous canes.

Amphidiploidy.—The phenomenon of doubling of chromosomes in one of the parents, first noticed by Dr. G. Bremer of Java, was studied in some detail, and the presence of ' amphidiploids ' or ' constant hybrids ' was indicated in certain interspecific and intergeneric hybrids with *Saccharum*. It would be idle to look for the usual segregation of characters in such hybrids. It was found that when the cane Vellai was crossed with other species of *Saccharum* or other genera, doubling of chromosomes takes place in certain cases but not in others. This would appear to be traceable to the presence of binucleate gametes in Vellai.

Origin of certain S. spontaneum types.—It was found possible to build up through suitable cross-breeding certain of the *S. spontaneum* types occurring in nature, thus providing experimental evidence about the origin of these forms (Plate V).

A genetic analysis of selfs and back crosses of interspecific hybrids has shown that the presence of the IV glume in a cane may be taken as indication of *S. spontaneum* blood in it. The awn present in sorghum is inherited as a dominant character when sorghum is hybridised with the Dehra Dun form of *S. spontaneum*; this character is not dominant when the cross is made with the

* The work described in this section is under Dr. E. K. Janaki Ammal and is financed by the Imperial Council of Agricultural Research.

Coimbatore form. The purple stigma of *S. spontaneum* is dominant to the yellow of sorghum in the intergeneric hybrids.

IV. OTHER INVESTIGATIONS

1. Sports through bud mutilation

In the previous report reference was made to the production of bud sports by mutilating the buds during their very early growth stages. A rather interesting sport that has thus been obtained by Mr. R. Thomas is a type of Co. 213 which possesses two or more buds on most of its joints (Plate V), the canes being thicker than the type. These are being propagated for further studies.

2. The 'Mungo' group of Indian Canes

The Mungo group of Indian indigenous canes possesses features of some interest. They are a class of high juice quality canes represented by different types practically throughout the sub-tropical sugar belt. They rarely flower even at Coimbatore. A rather complicated hybrid between the Java cane P.O.J. 2725 and two of the sorghums, *viz.*, *S. Sudananse* and *S. halapens* raised by Mr. R. Thomas has yielded types very similar to the Mungo group of canes.

3. Root Studies

Periodic studies of root-systems by methods previously described have revealed that, in certain canes, the periodic root flushes do not develop during the cold months and that early branching of roots is often correlated with growth vigour.

4. Cane germination

Pre-soaking of cane sets either in water or in solutions did not show appreciable results under Coimbatore conditions. This is perhaps attributable to the soil being surcharged with moisture at the time of planting. This is in consonance with similar results obtained in Barbadoes.

5. Resistance to saline conditions

Each year a batch of canes is grown in the most saline plot at the station, and irrigated with saline water. Besides Co. 285, Co. 331 and Co. 432 already found useful in this respect, Co. 355 and Co. 421 were added during the year. Co. 244 and Co. 419 were found to be moderately tolerant.

V. SUGARCANE BREEDING (MAINLY TROPICAL TYPES)*

1. Hybridization

Co. 419 now typifies the principal class of cane that is bred at the Thick Cane Area. The chief characteristics of this type are thick, heavy-yielding, vigorous canes, which are able to withstand a fair amount of drought. The following four crosses were effected on a bulk scale to produce such types : Co. 417 × Co. 413, Co. 417 × P.O.J. 2878, Co. 360 × Co. 413, and Co. 360 × Co. 408. These combinations were taken up on a bulk scale only after desirable seedlings were found to be produced from them in experimental crosses.

The second type is characterised by medium to thickish, hard-rinded hardy canes withstanding drought and frost. Co. 421 is now the standard for this class. Under this category the bulk scale crosses effected were : Co. 421 × Co. 360 and Co. 361 × Co. 285.

To the third class belong the thick juicy canes similar to Pundia and Poovan. For this class Co. 402 has been tentatively chosen as the standard and the bulk scale crosses effected to secure this type were : Co. 403 × P.O.J. 2727 and B. 3412 × Co. 413.

In addition to the above, thirty-four experimental crosses were made, certain of them with the object of evolving 'Early' and 'Late' canes.

2. Seedling plots

The improvement of the soil together with increased irrigation facilities by boring in Well No. 1 contributed towards successfully growing a fairly large number of seedlings in the first ground nursery. Nearly a hundred thousand seedlings were grown representing over eighty combinations. The seedlings, whose ovule parent was Co. 421, showed excellent vigour and good habit.

A feature of the second ground nursery was the large number of desirable type of seedlings that were available in quite a number of crosses. After a full year's growth 439 seedlings were selected for further test. This number is larger than that selected in any previous year.

3. Test plots

No outstanding canes were available from the 'Early' and 'Late' plots. From the mid-season or general plots the following canes were found to be fairly promising and were raised to the

*Carried out by Mr. N. L. Dutt, Second Cane Breeding Officer.

status of 'Co.' canes Their parentage is given elsewhere in this report: Co. 441, Co. 442, Co. 443, Co. 444 and Co. 445.

4. Ratoon plots

There were two ratoon plots, *viz.*, the first and the second year ratoons. In both these plots Co. 419 and Co. 421 gave good accounts of themselves. Co. 432 and Co. 413 were also good.

5. Type of seedlings yielded by different crosses

This study has been in progress for the last few years. One hundred seedlings are taken from each cross, and brix, weight of canes and number of tillers recorded of each individual seedling. This year thirty-six crosses were studied. The heaviest clumps were obtained in P.O.J. 2878 × B. 3412. The seedlings of Co. 421 × Co. 508 were fairly good in brix percentage, while those of P.O.J. 2878 × Co. 508 were relatively poor. Indications have also been obtained to the effect that from the tonnage point of view certain canes give better results when used as ovule parents than as pollen parents.

6. Floral characteristics of certain sugarcanes

In issuing botanical descriptions of important Co. canes the floral characteristics have not so far been taken into consideration. An examination of Co. 421 revealed a floral character that has, perhaps, not so far been recorded in the sugarcane. Co. 421 showed a very small but distinct structure resembling a third style with a few purple stigmatic papillae. It was found to be a constant and characteristic feature of this variety. In the large majority of other varieties the small protuberance was seen without the stigmatic papillae. In one floret of P.O.J. 920 three fully formed styles with stigmatic papillae were noticed.

Thick cane seedlings of P.O.J. 2725 were examined for the IV glume and a number of them were found to possess it. Thus Co. 361, Co. 407, Co. 417 and Co. 418 have the IV glume while in Co. 365—also a seedling of P.O.J. 2725—the IV glume not infrequently shows as awn. The IV glume is not present in Co. 349, while in Co. 408 it is present only occasionally. P.O.J. 2725 and its ancestors, P.O.J. 2364 and Kassoer, possess the IV glume. The presence of the IV glume in seedlings of P.O.J. 2725 may justifiably be attributed to the *S. spontaneum* blood.

A peculiar abnormality noticed in Shamsara was that the anther tips in a few cases were found to bear stigmatic papillae.

7. Germination of thick cane seed

One thousand pedicelled and an equal number of sessile spikelets were taken from eight lots of seed and sown separately. The

counts of germination made, confirmed the previous finding that sessile spikelets give better germination than the pedicelled ones.

8. Pollen shedding

About thirty varieties were studied for the effectiveness or otherwise of their pollen shedding. The extent of opening of the anther-sac and the amount of pollen available in the morning was recorded, and the quantity of pollen remaining over in the anther-sac in the afternoon was also noted. Varieties from which a fair quantity of pollen is available may be divided into two groups, *viz.*, (1) those containing a normal sized pore and devoid of pollen in the afternoon, and (2) those having some pollen in the afternoon despite possessing three-fourth to fully open anther-sacs. Of these the former were found to be better in that their pollen not only did not cake on the day of collection but also stored well.

9. Effect of chemicals on time of flowering

Attempts to alter the time of flowering in sugarcane by feeding the stalks with solutions of mercuric bichloride and ferrous sulphate were not successful. Two strengths of the solution were employed, *viz.*, 1 in 500, and 1 in 1000, and were fed through the artificially induced roots. The varieties used were Co. 285, Co. 421 and Co. 290.

VI. WORK AT THE KARNAL SUB-STATION*

1. General

This is the sixth year of the Substation. The area was extended from thirty to fifty acres and the scientific staff strengthened by the addition of a Technical Assistant.

Growth conditions during the year were very favourable with a mild summer, no winter frost, no cyclonic winds and no major pests and diseases except the borer. This resulted in a crop distinctly above the average.

2. 'Gur' value of the canes under test

The addition of a Technical Assistant rendered it possible to follow up the juice quality figures from October to March. Besides *gur* was prepared from five rows of canes each month—each row being 20 feet long—and notes recorded on weight and quality of *gur*. It was found that *gur* of fair consistency could be made even in the month of October and with canes showing as low as 13·18 per cent brix and 63·4 per cent purity. This *gur* found a ready market being early in the season. The *gur* figures

*The work described in this section is financed by the Imperial Council of Agricultural Research.

from October to March gave useful indications as to the best time for harvesting the canes. Co. 312 gave the highest yield in October, Co. 313 in January, Co. 341 in February and Co. 421 recorded the highest or very near it in all the months.

3. Barani trials

As already mentioned the summer drought was not severe enough to draw valid conclusions. Co. 285, Co. 313, Co. 421, Co. 341 and Co. K. 10 showed themselves thriving in this plot, particularly the last two which would appear to deserve further trial under such conditions.

4. General results

Co. 421 has fully justified the expectations and is easily the leader at Karnal. As general purpose canes, Co. 313 followed by Co. 312, Co. 331 and Co. 341, showed promise of usefulness as second line canes. It can now be said that a definite advance has been made on Co. 285, the present all-round cane of the tract. From the disease view point it is satisfactory that both Co. 285 and Co. 421 were found free from smut.

VII. DISTRIBUTIONS FROM THE COIMBATORE STATION

1. As seeds

Hybridized seeds of half a dozen combinations were sent to Mushari and Shahjahanpur in India and two other lots to Australia.

2. As seedlings

Over 5,000 seedlings employing as parents the now popular canes Co. 213, Co. 285, Co. 312, Co. 313 and Co. 331—some of them crossed with Co. 508, for early maturity—were sent to the Sub-station at Karnal. The sending of seedlings to Shahjahanpur was dropped as that station has now decided to import seed from Coimbatore.

3. As canes

Over hundred individual packages representing about forty varieties were sent to about thirty places in India and nearly twenty-five post parcels to foreign countries like the United States of America, Australia, the West Indies and Tanganyika.

VIII. PARENTAGE OF COIMBATORE SEEDLINGS

Co. 441 . . . P.O.J. 2727 G. C. (probable father D. 74).
Co. 442 . . . Vellai × Co. 243.
Co. 443 . . . P. O. J. 2878 × Co. 290.
Co. 444 . . . Co. 413 G. C. (probable father 247 B).
Co. 445 . . . Co. 417 × P. 1587 (Co. 281 × Co. 223).

IX. PERFORMANCE OF COIMBATORE CANES

Over the bulk of the sugarcane area in India the term 'improved canes' is increasingly becoming synonymous with Coimbatore canes. The steady improvement both in technique and the quality of parents employed at Coimbatore is releasing for trial to the various sugarcane testing stations of India a steady stream of new canes. The new canes often include some superior to the canes that had gone before them. Co. 205, for instance, has been replaced by Co. 285, and the testing stations in Sub-tropical India have already discovered Co. canes superior to Co. 285. The rather universal cane Co. 213 is again losing ground against types superior to it like Co. 290, Co. 312, Co. 313 and Co. 421.

The breeding of thick canes, started a decade and half after the main station, is getting to be felt in the provinces. By taking full advantage of the improved canes already obtained at Coimbatore and suitably hybridizing them with the best of other tropical types, the thick cane work is showing promise of steadily adding to the tonnage and quality of the Coimbatore productions. Of such, mention may be made of Co. 419 in tropical India, Co. 421 in sub-tropical India, and Co. 361 and Co. 412 in the North-West Frontier Province.

2. In foreign countries

In foreign countries like Natal, Louisiana, Australia, Brazil, Peru, Argentina and Cuba, certain of the Coimbatore productions are proving useful either by themselves or as parents. In cane literature it is now recognised that the Coimbatore station has been able to serve countries other than India for which the station was originally intended.

X. MISCELLANEOUS

A mixture of *Dolichos lablab* and *pillipesara* (*Phaseolus trilobus*) is now adopted as the standard green manure at the station, the latter closely covering the ground and suppressing weeds and the former growing above it. As much as 20,000 lb. per acre have been cut from such a mixed crop.

Large numbers of bamboos are used at the station for propping purposes. A good portion of the bamboo purchases during the year was treated with the Fal-Kamesam process to evaluate the money value of the process.

The method evolved at the station for sending canes overseas showed its efficacy for preserving the material alive for over seven months—a period which could easily take cane material even by ordinary steamer journeys twice round the world.

XI. PROGRAMME OF WORK FOR 1937-38

The breeding will be continued with the object of effecting further improvements in various directions. An attempt will be made to bring into the breeding programme new parents like sorghum and bamboo.

Studies will be continued with special reference (1) to seed and sett germination, (2) causes of sterility in sugarcanes and photo-periodism experiments, and (3) artificial production of sports.

Cyto-genetics studies on the intraspecific, interspecific, and intergeneric hybrids in the genus *Saccharum* will be continued to obtain data on the genetic composition and behaviour of *Saccharums*.

XII. PUBLICATIONS

1. Venkatraman, T. S., Rao Bahadur — A comparative study of certain morphological characters of sugarcane × sorghum hybrids (A review on the article by B. A. Bourne). *Ind. Jnl. of Agri. Sci.*, Vol. VI, Pt. IV, Aug. 1936, p. 996.

2. Janaki Ammal, Dr. E. K. and Singh, T. S. N. — A preliminary note on a new *Saccharum* × *Sorghum* hybrid *Ind. Jnl. of Agri. Sci.*, Vol. VI, Pt. V, Oct. 1936, p. 1105.

3. Venkatraman, T. S., Rao Bahadur — The sweetness of the wild sugarcanes of India. *Agriculture and Livestock in India*, Vol. VI, Pt. IV, July 1936, p. 517.

4. Krishnamurthi Rao, K. and Gopala Iyer, K. V. — Preliminary studies of the effect of arrowing (flowering) on sugarcane crop. *Agriculture and Livestock in India*, Vol. VI, Pt. V, September 1936, p. 667.

5. Venkatraman, T. S., Rao Bahadur — Sugarcane varieties: Major factor in crop improvement. *Agriculture and Livestock in India*, Vol. VI, Pt. VI, November 1936, p. 842.

6. ——————— — Sugarcane × Bamboo hybrids. *Ind. Jnl. of Agri. Sci.*, Vol. VII, Pt. III, June 1937.

SUGARCANE × BAMBOO HYBRIDS

FIG. 1

The hybrids P. O. J. 2725 P. O. J. 213

The two sugarcane parents successfully crossed with the bamboo

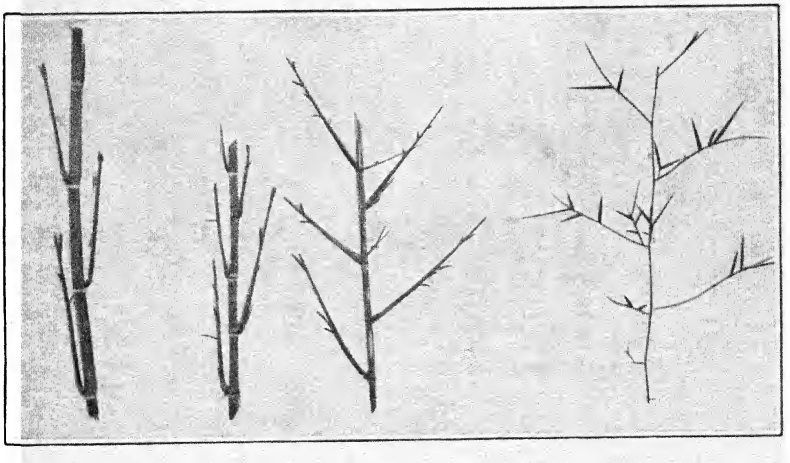
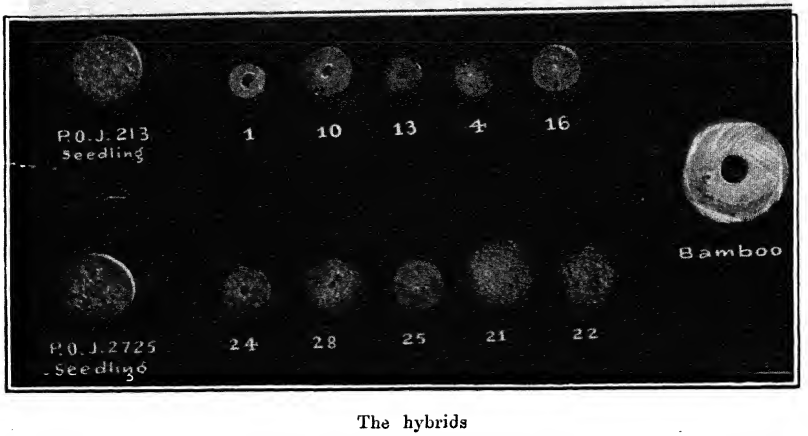


FIG. 2

P. O. J. 213 The hybrids Bamboo



The hybrids

FIG. 3

Multiple buds in Co. 213 sugarcane

FIG. 1

The Experimental Formation of INTRA SPECIFIC S.Spontaneum Hybrids

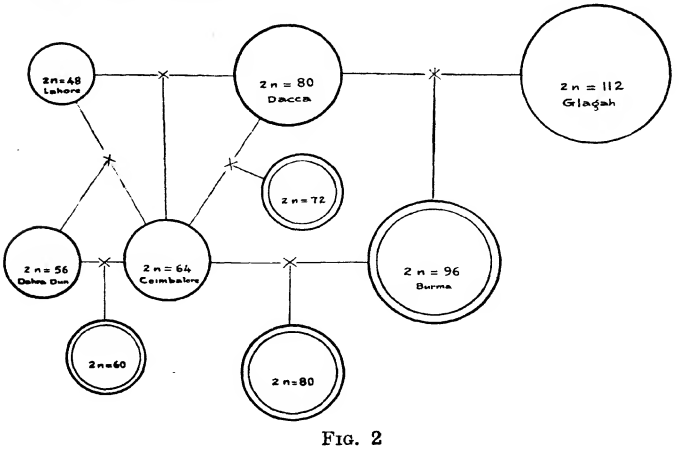


FIG. 2

Papers contributed to the Indian Science Congress held at Hyderabad during January 1937

1.	Dutt, N. L., Krishnaswamy, M. K. and Subba Rao, K. S.	A note on seed setting and seed germination in sugarcanes.
2.	Singh, T. S. N. . . .	Further contribution to the chromosome numbers in Indian *Saccharum spontaneum* L.
3.	Janaki Ammal, Dr. E. K. .	Tetrosomic inheritance in two *S. officinarum* × *S. spontaneum* hybrids.
4.	————————	The inheritance of habit in *S. spontaneum* L.
5.	————————	Chromosome studies in *S. arundinaceum* L.
6.	Krishnamurthi Rao, K. .	Studies on germination of sugarcane setts.

EXPLANATION OF PLATES

PLATE IV

Sugarcane × Bamboo Hybrids

Fig. 1. Shows the two main types of hybrids obtained from P.O.J. 213 × bamboo and the two sugarcane parents that have been successfully crossed with the bamboo. The plants are of same age and similarly treated.

Fig. 2. Of the two hybrids pictured one takes after the bamboo in the direction of the secondary shoot and early development of tertiary shoots. In the bamboo such tertiary shoots often develop into spines.

Fig. 3. Shows thick cross sections of the stem. The characteristic central cavity of the bamboo is seen in certain of the hybrids.

PLATE V

Multiple buds in Co. 213 sugarcane

Fig. 1. By artificial mutilation of the bud during the earliest stages of growth, it has been possible to induce in Co. 213 a tendency to multiple bud formation.

Fig. 2. The concentric circles represent types that exist in nature and have also been artificially produced—in the matter of chromosome numbers—by suitable hybridization.

REPORT OF THE IMPERIAL AGRICULTURAL CHEMIST

(B. VISWA NATH)

I. INTRODUCTION

The laboratories at Delhi were not ready for work till very late in the year under report. From June to November 1936, the staff of the Section was engaged at Pusa in the dismantling, packing and transport of the equipment to Delhi. For three months afterwards there were the unpacking, checking and placing the equipment in the respective rooms as the contractors made them available. The contractors completed the fittings of the several rooms by April 1937. The Section could get into normal working order only towards the end of the year. Nevertheless, the members of staff and post-graduate workers utilised every available opportunity for laboratory work and did what they could under the circumstances.

II. POST-GRADUATE STUDIES

The move was not allowed to interrupt the work of the post-graduate students under training. The students dispersed at Pusa at the end of May for their summer vacation, and when they rejoined at Delhi in July 1936 a few rooms were specially fitted up and gas and water were laid to enable to resume their normal programme of work.

Messrs. Sirajuddin Sadiquibhai (Bombay), M. A. Idnani (Sind), K. V. S. Satyanarayana (Andhra) and C. Parthasarathi (Madras) completed their two-year course at the end of October 1936. Messrs. M. A. Aziz (N.-W. F. Province), S. K. Mukerjee (Calcutta), G. Venkatachalam (Benares), B. Ramamurty (Allahabad) and P. Atmaraman (Andhra) were admitted to the course commencing from November 1936.

Mr. Gidwani was deputed by the Director of Agriculture, Sind, to undergo a course in Soil Science.

Messrs. A. Sen and M. V. Saradhy joined as research workers.

Mr. S. V. Ramanayya, who was awarded the M.Sc. degree of the Andhra University for his work done here on the "Chemistry of sulphitation process of sugar manufacture as applied to coloured sugarcanes", presented the same thesis and won the second prize of Rs. 500 awarded by the Advisory Council of Industrial Intelligence and Research.

III. RESEARCH AND INVESTIGATION

1. Soils

A beginning was made in the systematic study of the soil profiles of the agricultural land of this Institute and of the soils of typical tracts in the different parts of India.

Delhi soils.—The study of the physical and chemical characteristics of the profiles of the Delhi soils of the Institute has been taken up and is progressing rapidly.

All-India Survey.—This survey has for its object the appreciation in the first instance of the physico-chemical reactions in the formation of soils, and the genetic relationship existing in the profiles, with special reference to the influence of temperature, precipitation and evaporation. The data will then be utilised for the study of the interaction of manures and fertilisers and plant response. In this work stress has been laid on the importance of uniformity in the description of the profiles, collection and preparation of soil samples and their analysis by experienced analysts. Members of the Section with considerable experience in soil work toured in February, March and April 1937 in different parts of India and collected samples from uncultivated and cultivated areas. The several samples are under analysis, employing only such methods as have their limitations in respect to accuracy clearly defined and their general applicability established.

Manuring and cropping on the vertical distribution of soil constituents.—The effect of manuring and cropping on the vertical distribution of calcium carbonate in the calcareous soils of Pusa was studied, taking three inch borings down to a depth of five feet in the permanent manurial plots and the adjacent fallow land. The effect of manuring and cropping has developed two zones of high calcium carbonate concentration with a zone of low carbonate concentration lying between the two. This occurred in all the nine differently manured plots studied. In the fallow plot, however, there is a steady increase in carbonate concentration from the surface down to a depth of five feet. An interesting observation is that the total amount of calcium carbonate does not appear to be leached to lower depths but remains within the five feet depth, the change being in the distribution concentration in the different layers from the surface to five feet depth. From the measurement of moisture equivalents by the method of Briggs and McLean the texture of the horizons appears to vary with the carbonate concentration.

Mechanical analysis of soils.—Mr. A. T. Sanyal (post-graduate student) has examined the existing methods of mechanical analysis particularly in their application to soils rich in calcium carbonate,

and has shown tentatively that in the soils he has tested and from the data of other workers that calcium carbonate has little or no cementing effect and does not come with the clay fraction and that therefore preliminary acid treatment is unnecessary.

Soil nitrogen.—Further studies employing different methods for the estimation of nitrates in soil did not indicate evidence of photo-nitrification.

Sterilised solutions of sodium nitrite (0·24 per cent) with a pH range from 4 to 8·2 were not oxidised even after four months, while inoculation with nitrifying organisms and adequate air supply all the nitrite was oxidised to nitrate at all degrees of acidity, contrary to the findings of Corbet who reported inhibition at higher concentrations of acid.

In the decomposition and nitrification of calcium cyanamide in the soil a lag period in the oxidation of ammoniacal nitrogen was found to occur in certain soils. This lag was found by Messrs. Joshi and Hardayal Singh to be due to a reaction product soluble in one per cent hydrochloric acid but not to dicyandiamide, which in the concentration occurring in the water soluble form did not affect the activity of the nitrifying flora. A paper on the subject has been written up and submitted to the Indian Science Congress.

Chemical oxidation of nitrogen.—Mr. B. Ramamurty is engaged on the study of chemical activation of atmospheric nitrogen. His experiments show that in the atmospheric oxidation of phosphorus and potash and sugar nitrogen becomes "*hot*" or "*active*". This active nitrogen has been found to combine directly with tin and magnesium forming nitrides. It also combines with oxygen at low temperatures yielding ultimately oxides of nitrogen.

Cellulose decomposition.—In the course of investigations on enrichment cultures made for the study of cellulose decomposition Messrs. Joshi and Biswas discovered a new organism which grows and functions only in association with other non-cellulose decomposing organisms commonly occurring in soils and manures. The morphological, cultural and bio-chemical characteristics of the organism and of the other organisms associated with it have been studied, and the products of their metabolism and the quantitative dissolution of cellulose and nitrogen consumption as well as the nitrogen fixed by it in association with *azotobacter* were studied.

Azotobacter.—Further work in continuation of that reported previously was done on *azotobacter*. By serial transfers in broth *azotobacter* dissociated into several forms and these were isolated in pure cultures. None of these was capable of fixing nitrogen.

2. Manures, Fertilisers and Crops

Sewage utilization.—A new feature of work at this Institute is the utilization of sewage by the activated sludge process. The installation of the plant was completed a few months ago. Trial runs were made and the efficiency of sewage purification was tested by the periodical examination of crude sewage and the purified effluent. Continuous aeration resulted in biological oxidation sufficient to meet the rigorous standards laid down by the Royal Commission on Sewage Purification. Besides bio-chemical studies on the process, the effect of irrigation with the effluent on soil profile and the manurial value of sludge will be studied.

Varietal differences in plant nutrition.—The marked developmental contrasts in different varieties of the same crop are well known. These are explained as being due to their genetic composition but we have no knowledge from the physico-chemical and bio-chemical standpoints. Messrs. M. V. Saradhy and A. T. Sanyal have commenced preliminary studies on this important subject. Mr. Saradhy started work with Pusa 4, Pusa 12 and Pusa 165 wheats and has obtained some interesting preliminary data.

There are differences in moisture absorption and tissue hydration when the seeds are exposed to different moisture levels, and germination appears to depend on tissue moisture.

Mr. A. T. Sanyal has commenced the study on the absorption of nutrient elements by nine different families of plants growing under natural conditions. All the plants have been obtained from the Institute area. Confining his attention in the first instance to lime absorption, he has found that plants of the Gramineae family contain markedly less lime than those of Cucurbitaceae family. The Leguminosae occupy an intermediate position. Again, the plants of the Gramineae family yield ashes free from carbonate, while the others are characterised by the yield of ashes containing varying amounts of carbonates.

Movement of nicotine in tobacco and in grafts between tobacco and tomato plants.—Work on this subject reported previously was completed. Neither the seed nor the fruit contain nicotine which develops in the seedlings and disappears after flowering. The detailed analysis of several grafts between *N. rustica* (Pusa type 18 tobacco) and the Pritchard tomato, have shown that nicotine moves from tobacco stock into tomato scion but in reciprocal grafts no such movement appears to occur in the reverse direction from tobacco scion into tomato stock.

Investigations on sugarcane mosaic.—Messrs. Joshi and Datta investigated the sugarcane mosaic, and their work was directed chiefly to find out whether any organism or organisms are associated

with the mosaic tissue and whether such organisms have any definite cyclostages in culture as reported previously by Dr. Desai of this Institute. Experiments carried out with fresh sugarcane cultures month after month may be sharply divided into two sets. In the set of isolations from April to June, *i.e.*, before the break of monsoon, cultures made from filtered mosaic sugarcane juice developed the organisms, while mosaic leaf juices obtained between July and September yielded none. It would appear that season and growth of the sugarcane plant affect the life-cycle of the mosaic organism. The cultures obtained during the months of April to June yielded in eight out of ten cases organisms with cyclostages and similar to those described by Dr. Desai in appearance and reactions. Marked morphological differences were, however, observed sometimes in the different cyclostages.

3. Investigations on agricultural produce and industries

Improved process for the manufacture of gur and sugar by the open pan.—At the request of the Imperial Sugar Technologist the active carbon process for *gur* and sugar manufacture was demonstrated for two months at the All-India Exhibition at Lucknow. The process was afterwards tested for a week at the Sugar Research and Testing Station, Bilari. In one test the carbon process yielded on 64 hours maturing of *rab* 50 per cent dry bright sugar on *rab* polarising 97·6, while the ordinary process (no carbon treatment) yielded 35·1 per cent dull coloured sugar on *rab*. In another test with 112 hours for maturing *rab*, the sugar yield was 43·5 per cent on *rab*. The sugar crystals were brilliant and sparkling and polarised 98·9.

The new process has been under trial in several places. The administration report of the Bombay Department of Agriculture reports a recovery of 8 per cent on cane as against the usual 5 to 6 per cent without carbon treatment. The advantage of carbon treatment is that it removes even in the early stages a good portion of non-sugars and colloids which interfere with the crystallisation of sugar and its recovery. The process was demonstrated three times in and around Delhi and once at Meerut.

The process of manufacturing active carbon has been taken up by a firm in Calcutta and another in Bombay is likely to take it up.

IV. GENERAL ANALYTICAL AND CONSULTATIVE WORK

Samples of agricultural soils from Andaman Islands, samples of shora bone-meal composts from the Director of Agriculture, N.-W. F. P., and samples of coffee, tobacco and barley from the Agricultural Marketing Adviser and samples of drainage water from the Central P. W. D. were analysed.

V. PUBLICATIONS

1. Review on soil and fertiliser research for the publication Agriculture and Animal Husbandry in India—B. Viswa Nath.
2. The vicissitudes of nitrogen in the soil system—B. Viswa Nath.
3. Science and practice of Agriculture in India —B. Viswa Nath. Presidential Address, Agricultural Section, Indian Science Congress.

VI. PROGRAMME

The programme of work for the year 1937-38 will include :—

1. Study of soils formed under different conditions of rainfall, temperature and evaporation.
2. Nitrification and its significance in plant nutrition.
3. Nitrogen fixation in soils and crops.
4. Chemistry of sugarcane and *gur* manufacture.
5. Effect of soil conditions and plant nutrition on quality of crops.

REPORT OF THE IMPERIAL MYCOLOGIST

(B. B. MUNDKUR, SECOND ASSISTANT MYCOLOGIST)

I. ADMINISTRATION

Mr. L. D. Galloway, Imperial Mycologist resigned from December 13, 1936 and Dr. M. Mitra was placed in charge of the Section. Dr. Mitra took leave from June 16, 1937, when I was placed in charge.

II. TRAINING

Mr. S. C. Chowdhury completed his post-graduate training during the year and was admitted to the Associateship of the Institute. Mr. T. B. Lal Kulsherestha continued his studies. Mr. Nirankar Prasad was admitted to the post-graduate course. Mr. M. Ashgar Ginai, Mycological Assistant, Baluchistan Department of Agriculture, came to the Section in December to receive training for two months in the diseases of fruit trees and other crops.

III. DISEASES OF PLANTS

1. WHEAT

Loose smut.—Because of the danger involved in the treatment of wheat seed by the hot water method, Dr. Mundkur undertook the investigation on developing loose smut resistant varieties. Inbred seeds of forty varieties were sown at Pusa, and in February this year an adequate number of plants in each variety was infected with smut spores at the flowering time during anthesis. The seeds from each panicle have been separately harvested and the first year's results on resistance or susceptibility of the varieties will be available next year.

Bunt.—Studies on bunt in wheat caused by *Tilletia indica* have been continued by Dr. Mitra. Further experiments this year confirm the previous observations that the disease is soil-borne. Healthy seed sown in an infected plot after one year's rotation had shown bunt last year. This year's results indicate that even a two-year rotation is not adequate and that spores in the soil still retain their viability.

Six seed-treatment preparations, *viz.*, Ceresan Dry, Ceresan Wet, Agrosan G, Hortosan A, Gerimsan and sulphur dust, were tested to see how far these materials are useful as prophylactic agents to prevent bunt infection from the soil in healthy seed. The treatments were tried on three varieties of wheat and treated

seed was sown in properly replicated plots. Results indicate that substantial reduction in infection occurs by such treatment. Observations made to determine the relative resistance of some wheat varieties gave the following results :—

TABLE I

Resistance of wheat varieties to bunt at Karnal in 1936-37

Wheat type	Plot No.	No. of healthy ears	No. of bunted ears	Percentage of bunt
P. 80-7	7 (*i*)	1175	13	1·1
,,	7 (*ii*)	1018	..	traces
,,	Tika plot	1111	94	9·4
	General area			
P. 111	..	225	2	0·9
P. 165	..	116	1	0·89
P. 114	..	121	4	3·0
P. 120	..	201	3	1·4
P. 4	..	235	1	0·42
	Yield trial plots			
P. 80-5	Plot I	350	30	8·6
P. 165	,,	300	7	2·3
P. 126	,,	726	1	0·13
P. 122	,,	300	5	1·66
P. 125	,,	300	7	2·33
P. 4	Plot II	300	2	0·66
P. 125	,,	300	9	3·0
P. 120	,,	300	5	1·66
P. 12	,,	300	2	0·66
P. 80-5	,,	300	25	8·33
P. 121	,,	300	2	0·66
P. 124	,,	300	19	6·3
P. 114	,,	300	4	1·33
P. 165	,,	300	5	1·66

It will be noted that certain varieties show some susceptibility to the disease.

Foot-rot.—Studies on foot-rot of wheat have also been continued by Dr. Mitra. From diseased wheat seedlings, species of *Fusarium* and *Pythium* have been isolated. Numerous experiments to prove the pathogenicity of these organisms have met with failure, leading to the obvious conclusion that they were not parasitic.

2. OATS

Covered smut.—Spores of *Ustilago kolleri* collected in April 1935 and stored in sealed glass flasks were 90 to 95 per cent viable

and Dr. Mundkur found no falling off in their germination. They have again been used in all the infection experiments.

Resistance trials.—One hundred and one varieties were tested the previous year for determining their relative resistance to covered smut. In spite of heavy artificial infection, plants free from smut were found in each variety. From such plants Dr. Mundkur collected seed for trials during the year. This seed was artificially infected by the spores, germinated at 20-22°C. in an incubator from three to five days, and sown. Single plant selections had also been made and seed from these was sown separately, after infection and germination as usual. Many of the varieties have retained their resistance which they showed the first year, some others have shown increased resistance and the rest have proven extremely susceptible. Seed has been saved for further trials from the single plant progenies, among which selections have also been made.

Physiologic races.—As the differentials used in determining these races do not set seed under Pusa conditions, it is hoped to do this work at Delhi this year where the varieties are likely to mature as they set seed at nearby Karnal.

3. Barley

Foot-rot diseases.—These studies have been continued by Dr. Mitra. Species of *Helminthosporium* and *Alternaria* have been isolated from diseased seedlings as also from barley seed. A leaf-spot of mature barley leaves was found to be due to a species of *Alternaria* whose parasitism has been proved. The identity of these *Alternaria* spp. is under investigation.

Covered smut.—Spores of *Ustilago hordei* collected and stored in sealed glass flasks in April 1935 were found by Dr. Mundkur to be still highly viable. These were again used in the infection experiments to test the relative resistance of 68 types of barley. Seeds of these varieties were de-hulled, artificially infected with the spores, allowed to germinate in an incubator registering 20-22°C. for three to five days and sown. No smut developed this year also. Repeated failures to obtain smut in artificially infected seed is very intriguing and the matter is under careful investigation.

4. Nachni (*Eleusine coracana* G.)

A new disease of this crop was observed by Mr. Mehta at Benares. The principal symptoms were the prolific production of adventitious roots on aerial nodes right upto the top. No fertile shoots were produced by the plants which were stunted. In the phloem of the roots necrosis and bacteria-like bodies were present

The disease is under investigation but a preliminary note on it has been sent up for publication.

5. Potato

Late Blight.—Late blight due to *Phytophthora infestans* appeared in an epidemic form at the Simla Potato Breeding Station. From diseased material Dr. Mundkur isolated the causal organism which was compared with an authentic culture of *P. infestans* obtained from Baarn, Holland, and established its identity. The morphology of the fungus was also studied. Observations on the relative resistance of several indigenous and foreign varieties were made by the staff of the Potato Breeding Sub-station at Simla, and it was found that the variety President was fairly resistant while Pusa White, Gharwal, Coonor White and Darjeeling Red were slightly resistant. The species *Solanum andigenum, S. demissum, S. neoantipoviczii, S. antipoviczii* were highly resistant or immune to the disease at Simla. A paper jointly with the Botanical Section was written up and sent for publication.

6. Tobacco

Leaf Curl.—Collaborate investigations with the Botanical and Entomological Sections have shown that four viruses, designated A, B, C and D, can each bring about, independently, a leaf-curl with a definite set of symptoms in tobacco, and a fifth designated X has been found to be a mixture of any two of these. Dr. Mundkur was entrusted with the work of determining the methods of transmission of these viruses and finding out their properties. Attempts made to reproduce the diseases by the simple juice-rubbing and juice-rubbing with carborundum powder methods have proven negative, demonstrating that the viruses were not juice transmissible. The artificially treated leaves were later tested to see if any local lesions at least had developed. None had formed. A few tests were also made to make the white-flies, which are known to be the vectors, viruliferous by feeding them on virus-infected juice. The tests were too few and the results therefore are not conclusive. A more detailed account will be found as an appendix to the report on the scheme for research on cigarette tobacco, published by the Imperial Council of Agricultural Research.

7. Gram (*Cicer arietinum* L.)

Wilt.—A wilt disease of gram is very common in Northern India and it appeared in an epidemic form during the year at Karnal. Diseased plants from different varieties and different plots have been examined by Dr. Mitra and isolations have been made. In each and every case a *Rhizoctonia*, which resembles *R. solani*, has been isolated. Tentative observations show that all the gram

varieties are not equally susceptible to the disease and that soil conditions influence the course of the disease. Tests to note varietal susceptibility and the influence of soil conditions on the occurrence of the disease have been planned for the ensuing year.

Rust.—One of the diseases of gram which in certain years can by very serious is rust, due to *Uromyces ciceris-arietini*. The uredial and telial stages of this rust are known but it is not clear whether it is an autoecious or a heteroecious rust, what its alternate host may be if it is the latter; and if it is autoecious, whether the teliospores can infect gram plants producing pycnia and aecia. Above all the method of oversummering of the rust has also to be determined. Dr. Mundkur and Mr. Mehta have jointly undertaken preliminary investigations on this rust to find out some of this information. Uredial and telial material has been stored under different conditions and spore germination studies are in progress. Attempts to bring about infection by urediospores on detached gram leaves, floating in sugar solutions, have been successful and uredeo-sori have been obtained in such cultures. Teliospores have so far failed to germinate but it is hoped to make them do so using the different methods to break down dormancy or activate the enzymes which help in germination.

8. Apples

Fruit rot.—Apples received by the Imperial Entomologist for his codling moth studies were rotted by fungi. An examination of such fruit by Mr. Mehta indicated that the tissues were invaded by an intercellular mycelium with button-shaped haustoria, but no bacteria were present. The rotted apples emitted a fruity odour. Isolations from such fruit in almost all cases yielded a species of *Rhizopus* which in a majority of its morphological characteristics agrees with *R. arrhizus* Fischer. The parasitism of the fungus has been repeatedly tested on mature and immature fruits with positive results but a slight injury, a scratch or an abrasion, is necessary before the fungus can penetrate within. At 35°C. entire fruit have decayed rapidly in the course of 42 hours. The fungus grows well at 26-35°C. and best at the latter temperature. The fungus which seems to be a virulent wound parasite of apples is under study, firstly to determine its systematic position, secondly to see how the damage it causes can be controlled.

9. Sugarcane

Smut.—The smut of sugarcane was re-named *Ustilago scitaminea* in 1924 by Sydow when it became manifest that the previous name, *U. sacchari* Rabenh, had been incorrectly applied. Another smut with smaller spores and affecting *Saccharum fuscum* was called *U. consimilis* Sydow. Dr. Mundkur has examined fifty collections

of the smuts affecting the genus *Saccharum* comprising types, exsiccati and collections made at different places on different occasions. On the basis of size, colour, thickness of wall and surface characters of the spores a tentative conclusion has been reached that more than one species are responsible for bringing about the culmicolous smuts in the genus *Saccharum*. This hypothesis is being tested by an examination of more recent specimens collected from different sugarcane varieties and at different places. Herbarium specimens from foreign herbaria have been requested for, for further testing the hypothesis.

*Mosaic and other diseases of sugarcane**

(B. L. Chona, Plant Pathologist for Sugarcane Diseases.)

Tonnage Experiment.—A greater reduction in yield was noted with a thick Ponda variety as compared to previous experiments with Co. 213. This is in accordance with the view generally held that the thick cane varieties suffer heavy losses from mosaic disease.

Natural transmission.—The existence of natural transmission and slight secondary mosaic infection under Karnal conditions was observed during the year under report. Careful observations are being made to verify these indications of natural spread.

Distribution of mosaic within the cane.—Experiments with mosaic-affected canes of " Saharanpuri Surkha " variety show that, unlike in Co. 213, mosaic virus is distributed throughout the cane, judging from the development of the symptoms in plants grown from top, middle or bottom setts.

Treatment of setts.—In continuation of previous year's experiment, two hundred setts from mosaic clumps (" Saharanpuri Surkha ") were treated with salicylic acid, potassium iodide, clensel oil emulsion, pyridine, ammonium sulphate, malachite green, tannic acid and cold water to study their inhibitory effect on the development of mosaic. Setts treated with potassium iodide totally failed to germinate. None of the treatments except ammonium sulphate and tannic acid seemed to have any beneficial effect.

Thermal-death-point.—Mosaic leaf juice of Co. 313 was treated at different temperatures and then inoculated into young cane plants to test the infectivity. After repeated experiments, the thermal-death-point of Co. 313 has been found to lie between 50°C.-55°C. That of Co. 213 has already been determined and reported to be about 45°C. and that of M. 16 about 65°C. The fact that there are such vast differences in the thermal-death-point of the mosaic leaf juices from different cane varieties, suggests the existence of at

* Scheme for Research on Mosaic and other Diseases of Sugarcane financed by the Imperial Council of Agricultural Research. Detailed annual report already published by the Council.

least three distinct strains of sugarcane mosaic virus. These, for the sake of convenience, are classified as strain A, B and C according to their thermal-death-point, *i.e.*, those with "T. D. P." between 60-70°C. as strain A, between 50-60°C. strain B and between 40-50°C. strain C.

All the setts from the canes affected with strain A or B gave rise to clumps, all of which were affected with mosaic. The "recovery" was at the most negligible. In C the recovery was about forty to fifty per cent. Further more in A all the shoots in the clump showed mosaic with characteristic lesions even on the stem, while in B only fifty to sixty per cent of the shoots showed mosaic. These observations are supported by the mosaic distribution experiments conducted at Karnal (Punjab), Shahjahanpur (U. P.) and Pusa (Bihar).

Longevity.—Various trials of storing the mosaic leaf juice at different temperatures for varying periods and then inoculating into cane plants to test its infectivity, showed the temperature to be the most important factor in the storage life of mosaic virus : the lower the storage temperature, the longer the period the mosaic leaf juice could retain its infectivity and *vice versa.*

Cross inoculations.—Mosaic leaf juice of Co. 213, Co 313, M. 16, B. 6308, Saretha, Desi Ponda and Lalgira was inoculated into various varieties of cane and also into maize and sorghum plants. All took infection readily, producing typical mosaic symptoms. M. 16 mosaic juice made successful inoculations with Co. 213 which previously gave negative results at Pusa.

Seasonal variation.—Under Pusa conditions the months of May and June were found to be most suitable for successful inoculation. Similar seasonal influence was noticed at Delhi also, but the period for optimum infection seems to be slightly earlier (March-Mid May) than that for Pusa.

Plants inoculated in the evening (5 P.M.) showed 85 per cent infection, while the corresponding figure for morning (8 A.M.) inoculations was only 30 per cent.

Seed transmission.—Cane seedlings raised from selfed seed of Co. 313 affected with mosaic have remained perfectly healthy and free from any mosaic symptoms all through the season.

Growth in vitro.—Various attempts to grow the mosaic virus (L filtrate as well as mosaic leaf juice as such) in healthy leaf juice have been without success. On the contrary it has been found that the healthy leaf juice has an inactivating effect on the mosaic virus. The mixture of mosaic and healthy leaf juice in the proportion of 1 : 10 failed to infect the test plants, while the control juice gave 100 per cent infection.

Filter paper filtrate of healthy leaf juice had no such inactivating influence even after forty hours' interaction for the three different proportions tried—80 : 20, 50 : 50 and 20 : 80.

10. Brinjal (*Solanum melongena* L.)

A fruit-rot of this vegetable was observed on fruits purchased in the local market, and Mr. Taslim isolated a *Phytophthora* from the rotted tissues. The pathogenicity tests conducted have shown that the fungus is a virulent parasite. This rot on brinjals is probably a new record for India. Further work on this disease is in progress.

11. Pulses

A comparative study of different species of *Colletotrichum* which cause anthracnose in legumes has been continued by Dr. Mitra. Several fresh isolations have been made from diseased material collected at Delhi. Spores of some of the species have been detected on the seeds of *Dolichos lablab* indicating that these diseases may be seed-borne. Infection experiments on the relevant hosts have however given negative results so far. In culture some of the isolates of *Colletotrichum* have given the perfect stage, and attempts are being made to establish genetic connection by starting monospore cultures and finding out whether in such cultures the perfect (Glomerella) stage develops.

12. Cucurbits

Anthracnose.—This disease due to *Colletotrichum lagenarium*, which is supposed to be co-existent with its host, had not so far been reported to occur in India. It was found to do considerable damage to *kakri* (*Cucumis melo* L. var. *utilitissimus* Roxb.) and *kaddu* (*Lagenaria vulgaria* Seringe) in fields near Ferozepur. Brown spots first appear on the leaf which enlarge until the whole leaf is destroyed. Lesions occur on the petioles, stems and on fruits which do not mature properly and decay. The disease is under study by Dr. Mitra and a short note has been published on it.

13. Til (*Sesamum indicum*)

Leaf-spot.—A leaf-spot disease due to a species of *Macrosporium* which had not been observed before was found to do some damage to this crop at Pusa. In morphological characters Dr. Mitra has found that the fungus agrees with the description of *Macrosporium sesami* Kawamura. The disease is presumably seed-borne and it should be possible to appreciably control it by proper treatment. A species of *Pleospora* was also isolated from diseased seed but it has not been possible to find out whether this is the perfect stage of this *Macrosporium*.

14. Safflower (*Carthamus tinctorius*)

Leaf-spot.—Studies on the morphology, parasitism and taxonomy of a species of *Alternaria*, which causes leaf-spots, has been completed by Mr. Chowdhury. It may be noted that no *Alternaria* seems to have so far been reported on this plant.

15. Mustard (*Brassica* spp.)

Smut.—The pathogenicity of the root-gall forming smut, *Urocystis* sp., was tested by Dr. Mundkur on several species of *Brassica*, such as *sarson* (*Brassica campestris*), black mustard (*B. nigra*), *rai* (*B. juncea*), *toria* (*B. napus*), turnip (*B. rapa* var. *lorifolia*), cabbage (*B. oleracea* var. *capitata*) and radish (*Rhaphanus sativus*). Other crucifers that were included are *Turritis glabra* and *Mattheola sinuata*, hosts to which *Urocystis coralloides* is pathogenic. The fungus failed to attack these two plants but attacked the others with a varying degree of virulence. Morphological studies on the smut and histological studies of the galls were also made. The fungus has been found to be a new species and a paper has been sent up for publication.

16. Sunn-hemp (*Crotalaria juncea*)

The work on anthracnose disease of sunn-hemp due to *Colletotrichum curvatum* was brought to a close during the year by Dr. Mitra, and a paper entitled 'Anthracnose disease of Sunn-Hemp' sent up for publication.

17. Pigeon-peas

Wilt.—In the Botanical Section it has been found that rotating pigeon-peas with tobacco in wilt-infested land reduces wilt to some extent, and treating such fields with tobacco plant debris has also a favourable effect. The influence of tobacco products on the growth in culture of *Fusarium vasinfectum*, the causal organism of wilt, was tested by Mr. T. B. Lal who has found that tobacco root or stem infusions and even pure nicotine sulphate are without any deleterious effect on the growth of this fungus. Indeed the fungus grows vigorously on stems and roots of tobacco plants.

The growth of the same fungus in infusions of plants of susceptible and resistant varieties of pigeon-peas has also been tested. The infusions were sterilised both by using heat, and by employing a Seitz filter. No difference in growth of the fungus was found. The plants used were, however, mere seedlings.

In order to study the histology of penetration of the same fungus into resistant and susceptible varieties of pigeon-peas, Mr. Lal

grew seedlings and infected them on the radicle. Material of such plants has been fixed and embedded in paraffin. Microtome study will be taken up during the coming winter.

IV. MISCELLANEOUS

Basella rubra.—This vegetable crop was affected by an *Alternaria* leaf-spot at Delhi. Infection experiments carried out by Mr. Lal in winter gave negative results, but with the advent of the hot weather the fungus proved itself to be a weak wound parasite. It has been sent to the Imperial Mycological Institute for identification.

Hevea brasiliensis.—A species of *Colletotrichum* was isolated from diseased leaves of rubber plant received from the Mundakayam Valley Rubber Plantation. The Glomerella stage developed in culture and on leaves incubated in a moist chamber.

Physiological studies.—A preliminary study was made by Mr. Chowdhury on the effect of ultra-violet radiation on the growth and sporulation of some fungi in culture. Spp. of *Alternaria*, *Helminthosporium*, *Fusarium*, *Macrosporium*, *Colletotrichum* and *Phytophthora* which sporulated poorly on a culture medium were exposed to ultra-violet rays for different lengths of time. In *Colletotrichum graminicolum* mycelial growth was retarded but conidial production was accelerated. In other cases, the effect was uncertain. It was noted that several exposures of short duration were more helpful in hastening sporulation than a single prolonged exposure.

Rust slides.—These were exposed as usual, for Dr. K. C. Mehta of the Agra College, in the barley and wheat fields at Delhi from November 17 to March 15, 1937, and sent to him.

Publications.—Work in connection with the preparation of a list of fungi available in the herbarium is under active preparation. A supplement to Butler and Bisby's Fungi of India bringing the total number of fungi recorded for India, including Myxomycetes, to 2861 species, has been completed and is being sent up for publication. A host index of Indian fungi is also in preparation.

A list of new plant diseases recorded for India was sent to the International Institute of Agriculture, Rome, as usual. A chapter on plant diseases for the Review of Agricultural Operations in India, 1935-1936, was written by Dr. Mitra at the request of the Secretary, Imperial Council of Agricultural Research.

Culture Collections.—A fungal culture collection has already been started and there are at present 104 cultures of fungi available for distribution.

V. SYSTEMATIC WORK

The following more important accessions have been made to the herbarium, many of them being new records for the localities mentioned :--

Phycomycetes : *Cystopus candidus* on radish, Delhi ; *Peronospora brassicae* on mustard, Delhi ; *Peronospora trigonella* on *Trigonella foenicum græcum*, Delhi.

Ascomycetes : *Erysiphe graminis* on wheat, Delhi ; *Phyllachora cynodontis* on *Cynodon dactylon*, Delhi ; *Phyllactinia subspiralis* on *Dalbergia sissoo*, Delhi. *Dimerosporium mangiferæ* on mangœs, Sabour.

Basidiomycetes : *Graphiola phœnicis* on palm, Delhi ; *Urocystis brassicæ* on mustard, Pusa ; *Urocystis tritici* on wheat, Delhi ; *Ustilago hordei* on barley, Delhi ; *Ustilago tritici* on wheat, Delhi ; *Ustilago scitaminea* on sugarcane, Delhi ; *Sphacelotheca sorghi* on sorghum, Delhi ; *Tolyposporium ehrenbergii* on sorghum, Quetta. *Gambleola cornuta* on *Berberis nepalensis* from Mussoorie ; *Maseeëlla fluggeæ* on *Fluggea leucopyrus*, Delhi, *Phakospora vitis* on *Vitis semicordata*, Mussoorie ; *Puccinia cynodontis* on *Cynodon dactylon*, Delhi ; *Uromyces decoratus* on sunn-hemp, Delhi ; *Uromyces fabæ* on peas, Delhi.

Imperfect fungi : *Cercospora beticola* on spinach, Delhi ; *Colletotrichum graminicolum* on sorghum Delhi ; *Coniothecium chomatosporum* on apples, Chaubhatia ; *Septoria arcuata* on *Ficus indica*, Delhi.

The total number of accessions to the herbarium during the year is 125. New collections of fungi have been made at Dehra Dun and vicinity, Mussoorie and Saharanpur. These are now under study.

VI. PROGRAMME OF WORK FOR 1937-38

The plan of work for the year 1937-38 will include :—

1. Survey of plant diseases around Delhi.
2. Smuts and bunts of cereals and sugarcane.
3. Anthracnose diseases of pulses and cucurbits.
4. Leaf-curl disease of tobacco.
5. Fruit tree, fruit-rot and vegetable diseases.
6. Potato diseases.
7. Foot-rot and leaf-spot diseases of cereal and other crops due to spp. of *Alternaria* and *Helminthosporium*.
8. Rusts of gram and cereals.

9. Developing the herbarium and the central fungal culture collection.

10. Mosaic and other diseases of sugarcane.

VII. PUBLICATIONS

Chowdhury, S. C. . .	Germination of fungal spores in relation to atmospheric humidity. *Ind. Jour. Agr. Sci.* 7 : 653-6570. 1937.
Mehta, P. R. and Chakravarti, S. C.	A new disease of *Eleusine coracana* Gærtn. Sent for publication.
Mitra, M. . . .	An anthracnose disease of sunn-hemp. *Ind. Jour. Agr. Sc.* 7 : 443-4490. 1937.
———— .	Studies in the stinking smut or bunt of wheat in India. *Ind. Jour. Agr. Sc.* 7 : 458-4780. 1937.
———— .	Chapter on plant diseases for Agriculture and Animal Husbandry in India for 1935-1936. (in press).
Mundkur, B. B. . .	Host range and identity of the smut causing root-galls in the genus *Brassica*. *Phytopathology* (in press).
———— .	*Urocystis sorosporioides* ; a new record for India. *Trans. Brit. Myc. Soc.* (in press).
———— .	Anthracnose of cucurbits in the Punjab *Current Science*. 5 : 647-648. 1937.
———— .	Phytopathology and Mycology in 1935. Rev. of Biochem. and Allied Res. in India in 1935. 6 : 100-112, 1936.
———— .	Phytopathology and Mycology in 1936. Ann. Rew. of Biochemical and Allied Res. in India. 7 : 120-129. 1937.
————	Annual recurrence of Rust in Eastern Asia. *Current Science*. 5 : 306--307. 1937.
————, Pal, B. P., and Nath, P.	Relative susceptibility of some wild and cultivated potato varieties to late blight at Simla in 1936. *Ind. Jour. Agr. Sc.* 7 : 627-637. 1937.

The following abstracts were contributed to the Indian Science Congress, Hyderabad sessions, 1937.

Mitra, M. . . . Soil infection as a factor in the transmission of wheat bunt.

———— . Effect of bunt (*Tilletia indica*) on wheat.

———— . An anthracnose disease of sunn-hemp.

REPORT OF THE IMPERIAL ENTOMOLOGIST

(HEM SINGH PRUTHI)

I. INTRODUCTION

The research work of the Entomological Section was naturally considerably interrupted due to the move of the Institute from Pusa to Delhi. Though actually the staff, insect collections, library, laboratory apparatus, etc., were on the move during August and September (1936) only, the work of packing and unpacking which preceded and followed the actual move took us at least six months. Thus practically no research work could be started at the new site till December. The work was again similarly interrupted during summer when a great majority of insects under study died due to excessive heat.

II. TRAINING

Mr. K. V. Rao, post-graduate student, completed his course in October and was appointed as Research Assistant in the Sugarcane Scheme. Mr. R. L. Garg was under training throughout the year. Messrs. R. L. Gupta and C. B. L. Bhargava joined the post-graduate course in November 1936. Mr. A. P. Kapur, M.Sc. (Zoology), University of the Punjab, was under training for a short period of about three months from February to May 1937. The Entomological Assistant and a Fieldman of the Agricultural Department, Baluchistan, were under training for about two months from 4th December 1936.

III. SPECIAL INVESTIGATIONS

I. PESTS OF SUGARCANE

The Imperial Council of Agricultural Research sanctioned a scheme of research work on the pests of sugarcane, and the Second Entomologist, Mr. P. V. Isaac, was put in independent charge of this scheme on 1st April, 1936. He has submitted a separate report on these pests. In the main Section the data collected during the two previous seasons regarding the incidence of borers on five common varieties of cane planted side by side on a randomised plot at Pusa were tabulated and statistically examined. The chief conclusions are given below.

Species of top-borers occurring at Pusa consisted of *Scirpophaga nivella* and, rarely, *S. monostigma*. The stem-borers included *Diatræa sticticraspis*, *D. venosata* and *Chilo zonellus* representing about 80 to 85 per cent, 15 per cent and 3-5 per cent of borer population respectively. *Emmalocera depressella* was the only root-borer.

The dead-hearts caused by the various borers appear in April. As the season advances all the three borers become more active and cause the maximum number of dead-hearts during June and July. During the monsoon months their activities decrease but soon after the rains are over they are active again. The damage caused by the top-borer is especially very heavy during autumn. This pest remains active almost throughout the year, whereas the dead-hearts caused by the stem and root-borers are comparatively few during winter. The susceptibility of various varieties of cane to stem-borers, top-borers and root-borer is indicated in the following table :—

	Stem-borers	Top-borers	Root-borers
Least susceptible	Co. 299	313 331	299 313
Moderately susceptible . . .	Co. 331	299	210
	Co. 210	213	213
Most susceptible	Co. 213	210	331

Taking all the borers into consideration, Co. 313 and Co. 299 seem to be the most resistant, Co. 331 being intermediate and Co. 213 and 210 being the least resistant.

The incidence of various borers being equal, the stem-borer actually does more damage than either of the other two in reducing the weight and sucrose content of cane, the top-borer is next in importance and the root-borer does not do any appreciable damage to the cane when it is about 4—5 months old. Two papers on the subject have been prepared for publication.

The work on the life-history of the Neuropterid, *Coniopteryx pusana*, a predator on the eggs of *Pyrilla* pests of cane, was completed. This predator makes its appearance in the field at Pusa in the last week of July. Eggs are laid singly near the egg-masses of *Pyrilla* and hatch in about 3-4 days. The freshly hatched larva searches out the host eggs and feeds on them. The larval period is completed in about 20 to 25 days. The full-grown larva spins a double cocoon for pupation. The pupal period during the rainy weather is 9 days. A paper has been prepared on this subject.

A critical study of the identity of various species of *Pyrilla* infesting cane in India was also completed. It was concluded that true *P. aberrans* is yet not known to occur in India and the species which has been called by this name in literature is actually *P. pusana*. A paper on the subject has been published.

2. Insect vectors of tobacco leaf-curl

Transmission experiments were performed during the year under report to confirm the tentative conclusions arrived at in

the previous year about the role of the white-fly *Bemisia gossypiperda* M. and L., in the transmission of the disease from sunn-hemp to healthy tobacco. This insect was also studied to ascertain if it is also concerned in the transmission of the disease from tobacco back to sunn-hemp and from tobacco to tobacco and sunn-hemp to sunn-hemp. Several series of transmission experiments were performed at different times of the year (September 1936 to February 1937) on tobacco seedlings of different ages to determine the season when the vector is most abundant and the age of tobacco when it is most susceptible to virus infection. The inoculated plants were kept under observation up to the middle of April 1937 for noting the appearance of the disease. H 142, the most common cigarette variety of tobacco at Pusa, was under investigation.

(*i*) *Transmission of the disease from sunn-hemp to tobacco.*—Five series consisting of 42 transmission experiments were performed between September and December 1936 on healthy tobacco seedlings 8-16 weeks old. The diseased sunn-hemp used as source in these experiments was sown in the field about 1st July. About 50 per cent. of experiments gave positive results when the inoculations were done between the end of October and first week of November with seven weeks old tobacco seedlings. In most cases the inoculated tobacco developed 'A' type disease as last year. All the controls remained free.

(*ii*) *Transmission of the disease from tobacco to sunn-hemp.*—Four series consisting of 32 experiments were performed to determine if the vector can transmit the disease from tobacco back to sunn-hemp. 1-31 specimens of the bug were kept on tobacco, suffering from A, B, C and X types, for 12-48 hours and then transferred to healthy sunn-hemp. Inoculation experiments were performed between the middle of September and 6th November. The sunn-hemp seedlings under experiment had been sown about the beginning of July. Two of the inoculated seedlings exhibited some reaction but in no case the disease developed typical leaf-curl.

The incidence of leaf-curl in sunn-hemp in the field at Pusa is generally serious in August. The failure to transmit the disease from tobacco to sunn-hemp may be due to the fact that sunn-hemp at the time of experiment (September-November) had passed the stage of growth when it was susceptible to infection.

(*iii*) *Transmission of the disease from sunn-hemp to sunn-hemp.*—Two series of experiments were performed to ascertain if the white-fly is also concerned in the transmission of the virus from the diseased sunn-hemp to healthy sunn-hemp.

Twenty-four experiments with 4-12 specimens of white-flies previously kept on diseased sunn-hemp for 24 hours were performed between 8th and 13th October. Four of the inoculated plants

developed leaf-curl almost similar to that of the source. In one case side shoots also became diseased. All the controls remained free from the disease.

Thus the transmission of leaf-curl is also possible from diseased sunn-hemp to healthy sunn-hemp.

(*iv*) *Transmission of the disease from tobacco to tobacco.*—Seven series consisting of 269 experiments were performed to ascertain the role of the white-fly in the transmission of different types of leaf-curl from diseased tobacco to healthy tobacco. The results of various experiments are summarized in the following table :—

Series	Time of experiment	Age of healthy tobacco seedlings inoculated (weeks)	Total No. of experiments performed	Number of experiments which gave positive results
i	14th to 29th September 1936	9-11	17	2
ii	8th to 15th October 1936	12-13	17	1
iii	16th to 17th October 1936	9	4	2
iv	28th October to 6th November 1936	6-7	51	18
v	14th to 16th December 1936	about 8	33	4
vi	25th Dec. 1936 to 5th Jan. 1937	6-8	67	13
vii	6th to 9th February 1937	about 7	80	15

From the foregoing it is evident that the white-fly is the vector concerned in the transmission of the disease from tobacco to tobacco, and that all the five types of leaf-curl can be transmitted by it individually and in combinations. It will be evident that the vector was most capable of transmitting the disease from the end of September to the middle of November, and that the tobacco was most susceptible to infection when it was about seven weeks old.

(*v*) *Another alternate host of the virus.*—*Ageratum conyzoides*, one of the common weeds at Pusa, was found to be severely infected with a leaf-curl disease, having symptoms similar to tobacco leaf-curl. Six transmission experiments were performed in December 1936 to ascertain whether this weed acts as an alternate host of the tobacco leaf-curl virus. Six to sixteen specimens of white-fly were ensleeved on diseased *Ageratum* for twenty-five hours and then transferred to nine weeks old healthy tobacco seedlings. Two plants out of six plants thus inoculated developed leaf-curl of D type.

(*vi*) *Alternate host plants of the white-fly vector.*—A survey of the food-plants, other than tobacco, of the white-fly was made at Pusa and the species was found feeding and breeding on the following :—

1. *Gossypium herbaceum* (cotton).
2. *Crotalaria juncea* (sunn-hemp).
3. *Solanum melongena* (brinjal).
4. *Anisomeles ovata* Br. (wild *ber*).

3. The Linseed midge *Dasyneura lini* and its parasites

Work on the morphology and bionomics of the linseed midge was continued at Pusa during the year under report. The eggs are laid singly or in small batches in the folds of the calyx of unopened buds. On hatching the young larvæ attack the internal organs of the bud as a result of which the corolla gets decolorised and crumpled, bud fails to open and setting of seed does not take place. In February the larval period lasts for six or seven days, but towards the end of the linseed season, *viz.*, about the middle of March when it gets fairly warm at Pusa, a great majority of full-grown larvæ, instead of pupating normally, enter a quiescent stage. It is surmised that probably the pest passes the unfavourable summer in this stage.

It appears that the relative incidence of the pest on various varieties of linseed is very much dependent on the time of their flowering. The varieties flowering after the middle of February, when the breeding of the pest is very active, were found to suffer most.

All the stages of the midge on linseed have been carefully compared with those occurring on *Cajanus Cajan*. It is almost certain that both are one and the same species ; thus *Cajanus Cajan* seems to be an important alternate host plant of the pest. This midge previously recorded at Pusa was found this year infesting linseed at Karnal also. It is therefore evident that the pest is widely distributed in North India.

Parasite of Dasyneura lini.—A chalcid larval parasite of the linseed midge was discovered during this year and studied in some detail. The parasite is yet awaiting identification.

The eggs are laid singly inside the crumpled and unopened buds of linseed containing almost full-grown larvæ of the midge but rarely on the host larvæ themselves. The parasite eggs were never found in healthy buds nor in buds containing young host larvæ.

These facts show that the parasite exercises a great amount of selective power.

During February the egg stage lasts about three to four days. At a constant temperature of 18°C. it is about two to three days.

The freshly hatched grub is fairly hardy and is capable of wandering about for twenty-four hours or so without taking any food. Thus the fact that the eggs are not laid on the body of the host is not a serious handicap to the parasite. On coming in contact with the host, the young parasitic grub attaches itself to the latter's body and begins feeding on the liquid juice without damaging the essential organs of the host. In the beginning it is colourless and semi-transparent but soon becomes yellow and finally assumes the pinkish orange colour similar to that of the host. The larval period lasts for twelve to fifteen days at 18°C. During this period the grub consumes three to four host larvæ and this number is usually always available in one flower bud.

The full-grown grub pupates within the flower bud and emerges as adult after eleven to thirteen days at 18°C.

The whole life-cycle is thus completed in a little less than a month (average twenty-eight days) at 18°C.

The anatomy of the various stages of the parasite has also been studied.

4. The Tur-pod Agromyza

A preliminary account of the life-history of this fly was given in the last year's report. The fly has since been identified as *Agromyza obtusa*. This species was first described by Mallock in 1914 from six specimens sent him from Formosa, Japan, though it was recorded as an important pest of *Cajanus Cajan* in India as early as 1906. It occurs throughout India and is met with in the field during early winter and spring only. Observations on the seasonal history of the pest show that it starts its activity in October-November when pod formation commences on *Cajanus* plants. The first batch of eggs was observed in the field on 11th October; by the end of November oviposition appeared to have stopped altogether. During December and January only a few full-grown larvæ and pupæ were available in the field. A large number of the pupæ collected during this period were found to be dead. In February, as soon as the days warmed up, the flies began to emerge and started ovipositing again. The breeding is at its maximum during March and April. Thereafter the crop is harvested and it has yet to be determined how the fly passes the summer season from May to September. No alternate food-plants are yet known.

5. Pests of stored grain

Attempts were made to study the life-history of stored grain pests in the laboratory. Some experiments were also performed to determine the repellant effects of ashes and various clays on the pests. During May the temperature in the laboratory rose so high and the humidity was so low that all species under observation underwent abnormally high mortality. For example, *Calandra oryzæ* infesting wheat brought from Karnal went on multiplying up to the end of March, but during April and May the adults left the grains, came on to the surface and began to die there in large numbers. Similarly *Sitotraga cerealella* and *Corcyra cephalonica* adults copulated and oviposited during April, but the eggs did not hatch in the former case and the larvæ hatched in the latter case did not survive more than a few days.

6. Fruit-flies

Fruit-flies constitute very serious pests of various fruits in India and our knowledge of their biology, life-history, etc., is very much limited. At the request of the Director of Agriculture, North-West Frontier Province, an investigation of these pests with a view to their control was undertaken last summer. A preliminary survey of various important fruit tracts of that province was made in May. The following species occur in this area: *Chaetodacus ferrugineus* Fabr., *C. zonatus* Saund, *C. cucurbitae* Coq., *Carpomyia vesuviana* Costa., *Myiopardalis pardalina* Bigot. and *Dacus oleae* Silv. During May the pest (*C. ferrugineus*) was most serious at Kohat, where loquat and apricot were infested to the extent of fifty to sixty per cent.

The fruits of ak (*Calotropis* sp.) were found infested at New Delhi by the fruit-fly *Dacus longistylus*. The life-history of this fly was studied. The female pierces the fruit and lays eggs in batches. Up to fifty eggs were found in two batches in one fruit. The young maggots feed on ovules with the consequence that the fruit withers and dries up.

7. Codling moth

About two years ago the Imperial Entomologist reported (*Agric. and Liv.*, V) that the notorious codling moth occurs in Baluchistan. This was the first definite record of the occurrence of this pest in India. Recently the Imperial Council of Agricultural Research sanctioned a scheme for the survey of this pest in Baluchistan to ascertain its exact distribution and economic status. The work under this scheme was started in May. The Imperial Entomologist himself toured in the important apple-growing tracts of Baluchistan and has collected data which indicate that codling moth is

very widely distributed in that province and that it is a very serious pest in certain tracts, *e.g.*, Quetta—Pishin, Fort Sandeman, etc. The survey will be completed in another couple of months and the detailed observations and conclusions will be reported next year.

It is of interest to add in this connection that the Imperial Entomologist has also reported the occurrence of codling moth in the North-West Frontier Province.

8. Ecology of some common parasites of spotted bollworms of cotton

A study of the ecology of some common parasites of the spotted bollworms (*Earias fabia* and *E. insulana*) was undertaken in the beginning of the present cotton season (in May) and thus has been in progress for about two months at the time of writing the report. Before cotton was found infested, the bollworms were chiefly collected from *Hibiscus esculentus*, *Abutilon indicum* and *Althea rosea*. Contrary to previous records, both *fabia* and *insulana* larvae in *Hibiscus esculentus* were found parasitised by *Microbracon lefroyi*, *Actia aegyptica* and *Elasmus* sp. Maximum parasitisation by *Microbracon lefroyi* alone has been so far about 10 per cent in the field. Some preliminary observations on the development of *Microbracon lefroyi* at different constant temperatures and humidities have been made to determine the threshold of development and optimum conditions for its multiplication.

IV. OBSERVATIONS ON OTHER INSECTS

After the shifting of the Institute to New Delhi a careful study of the insect fauna of the Delhi Province and its neighbouring districts was undertaken. As expected, several insects in this environment are new, whilst the behaviour and seasonal history of those which also occur at Pusa is different. Moreover, due to the summer being very hot and dry here, the technique of rearing insects in the Insectary has presented several unexpected difficulties.

About 120 different insects have been reared in the Insectary, of which several are awaiting identification. Those which have been named and are of comparatively more interest are listed below:—

I. Insects found feeding on crops of economic importance

(1) *Plusia orichalcea* Fb. larvæ on leaves of *Brassica campestris*, *Pisum sativum*, *Carthamus tinctorius*, *Lathyrus sativus*, *Helianthus annuus*, *Trifolium alexandrinum* and *Althaea rosea*.

On *Helianthus annuus* plants the caterpillars occurred in good numbers.

(2) *Plusia ni* Hb. in small numbers on leaves of cabbage and *Eruca sativa*.

(3) *Laphygma exigua* Hb. caterpillars on leaves of *Carthamus tinctorius*, *Pisum sativum*, *Brassica olevacea* (cabbage), *Lathyrus sativus*, *Trifolium alexandrinum*, *Eruca sativa*, *Brassica campestris*, *Cicer arietinum* and *Ervum lens*. The pest was not bad on any of the crops.

(4) *Agrotis flammatra* Schiff. on leaves of *Cicer arietinum*.

(5) *Agrotis ypsilon* Rott. on leaves of *Pisum sativum* and *Lathyrus sativus*, in small number.

(6) *Chloridea peltigera* Schiff. on leaves of *Helianthus annuus* in small number.

(7) *Earias insulana* Boisd. in fruits of *Malva sylvestris*; bad pest.

(8) *Cirphis unipuncta* Haw. on leaves of *Lathyrus sativus* in small number.

(9) *Euproctis fraterna* Moore on *Ricinus communis* leaves in a very small number; *Euproctis lunata* Walk. in large numbers on the same host. (*vide* Figs. 3 and 4, Plate VI)

(10) *Dasychira securis* Hb. on leaves of *barro* (H) and *Cyperus rotundus* in small number.

(11) *Porthesia xanthorrhœa* Koll. on leaves of *Althœa rosea* in small number.

(12) *Euchrysops cnejus* Fb. larvæ boring pods of *Vigna catjang* in small number.

(13) *Lampides bœticus* L. larvæ boring pods of *Pisum sativum*.

(14) *Plutella maculipennis* Curt. larvæ feeding on leaves of cabbage, *Eruca sativa*, *Brassica campestris* and *juncea*, in small number.

(15) *Platyedra gossypiella* Saunders larvæ boring seeds of cotton; bad pest at Gurgaon and Rohtak.

(16) *Phytomyza* sp. ? maggots mining leaves of mustard, *Eruca sativa*, *Pisum sativum*, *Trifolium alexandrinum*, *Brassica juncea*, *Melilotus indica*, *Althœa rosea*, *Malva sylvestris*, *Solanum melongena*, *Helianthus annuus* and *Carthamus tinctorius*.

(17) Aphides were noted on barley, *Lathyrus sativus*, wheat, oats, knolkohl, cabbage, radish, tobacco, turnip and *Hibiscus esculentus*.

Aphides occurred as a very bad pest on mustard (*Eruca sativa*) and other cruciferous plants at Delhi, Gurgaon and Rohtak (Figs. 1 and 2, Plate VI).

(18) Fruit-fly maggots (Dacus sp.) found boring unripe fruits of *Cucumis melo* (*kharbuza* and *kakri*) and *Luffa ægyptiaca*; serious pest.

(19) The *Ak* grasshopper *Pœcilocerus pictus* Fb. was found bad on *Solanum melongena* in Shadipur. They attacked *Solanum melongena* plants after defoliating *Calotropis gigantea*. Spraying with usual doses of lead arsenate and sodium fluosilicate proved unsuccessful. A special study of the control of this species has been undertaken.

(20) Some Bruchids were found heavily infesting ground chillies at New Delhi.

(21) Some rotting apples attracted a large number of adults of the beetle *Carpophilus dimidiatus*.

(22) *Empoasca devastans* appeared in large numbers on late sown *bhindi* in the Estate in the last week of June.

(23) A serious infestation of mites on *bhindi* plants in Wazirpur village (Delhi) was noted in the last week of June. The entire plants were covered with webs. However a heavy shower of rain washed away the mites.

(24) The fruit-fly belonging to the Genus *Aciura*, R. D. was reared from the fruits of *Lantana*.

(25) *Anopheles subpictus* Grassi was found breeding in the pond near the Estate in October 1936 and June 1937. *Culex fatigans* was found breeding in small dirty collections of water in the Estate from October 1936 to June 1937.

(26) The larvæ of the Syrphid fly *Paragus serratus* Fab. were found predating on aphids on *Dolichos* in October 1936.

(27) Rotten meat and the fly bait set up for attracting house-flies was found to attract a fair number of Dermestid beetles, *Dermestes vulpinus*, Histerid beetles of *Saprinus* sp. and some Cleridæ.

(28) A number of grubs of apparently two different species of Dytiscidæ were found feeding on mosquitœ larvæ in a pond near the Institute.

(29) *Polistes hebrœus* were observed in large numbers from March onwards. The females were active building nests in houses and also on plants in the fields.

(30) The Cricket—*Gryllodes sigillatus* is very common at Delhi and causes much nuisance in the house-hold. It breeds actively from the rainy season and is found in large numbers till the onset of winter. It again increases in

numbers during spring. It causes much damage to clothes in boxes, as well as to those on pegs, etc., spoils stores in the kitchen and pantry.

(31) Swarms of Termites appeared with the first showers of rains during the month of June. They were attracted to lights in large numbers. Out of the two species collected one belongs to the genus *Odontotermes*. The winged sexuals were found being eaten by lizards and rats very greedily.

(32) *Atractomorpha crenulata* was found attacking vegetables. Many Acrididæ were attracted to light at night. A number of Mantidæ were found feeding on the insects attracted to light.

(33) Ripe and smutted heads of *juar* were found infested by a black tiny beetle of the family Endomychidæ in December.

2. Parasites

A large number of parasites bred from various insect pests have been examined. The more important parasitic species are mentioned below and are figured in Plates VII and VIII.

Ichneumonidæ.

Rhyssa persuasoria L. On wood feeding grubs of *Sire* sp.

Xanthopimple nursei Cam. On larva of *Chilo simplex*.

Braconidæ.

Microbracon gelachidiphagus Ayyar (?) on larvæ of spotted bollworm *Earias insulana*.

Microplitis similis Lyb. on the cutworm *Agrotis ypsilon*.

Microplitis eusirus Lyb. on the castor semi-looper *Achæa janata*.

Bracon fletcheri Silv. on maggots of the fruit-fly *Carpomya vesuviana* Acosta.

Apanteles sp. on larvæ of *Sylepta lunalis*, the grape leaf-roller.

Apanteles glomeratus Linn. on the caterpillars of *Pieris brassicæ*, the cabbage butterfly.

Chalcidoidea.

A Chalcid, on larvæ of *Dasyneura lini*, the linseed midge.

Asympiesiella india Girault. on larvæ of *Gracillaria soyella*, leaf-roller of *Cajanus Cajan*.

C. Other noteworthy insects collected on wing or found feeding on wild plants

Danais chrysippus L. on leaves of *Calotropis gigantea.*

Tarucus theophrastus Fb. on leaves of *Zizyphus jujuba.*

Precis orithya L. on leaves of *Convolvulus fluricaulis* Choisy var. *mœra.*

Pyrameis cardui L. on leaves of *Malva sylvestris.*

Scutellera nobilis Fb. on leaves of *Zizyphus jujuba.*

A swarming Cecidomyid.—Swarming in *Cecidomyidæ* is not a very common phenomenon and no Indian species has been known to swarm. Several swarms of a species of *Micromyia* Rondani (probably a new species to science) were observed in the vicinity of the Entomological Laboratory at New Delhi on Sunday the 28th February 1937 at about 10 A.M. The swarms disappeared at about 4 P.M. There were thousands of small black midges in each swarm. The swarms continued to appear every day in the laboratory compound for about ten days. A note on the subject has been prepared for publication.

V. INSECT COLLECTIONS

A great deal of time was spent on properly pinning, fixing in position and packing the myriads of insect specimens in our collection to avoid damage to them during their transit from Pusa to Delhi. Keeping in view the fact that some of the dry specimens were over 30 years old it is very gratifying to record that the damage during transit was almost negligible. However due to delay in the completion of the new laboratory at Delhi, on account of heavy rains, etc., the collection remained packed up for considerable time with the result that several specimens got mouldy. As soon as proper facilities for storing the collections became available, they were unpacked and the damaged specimens were cleaned and repaired.

The registration and card cataloguing work of the named collection which was begun last year was continued as soon as we settled down at New Delhi, and about two thousand species consisting of about twenty-five thousand specimens were catalogued up to the end of the year under report.

A part of the unnamed collection of the Section has been sorted out and named with the help of outside specialists when necessary. Our named collection has thus been enriched by the addition of about 150 species. Specimens of about 350 species received in donation and exchange have also been incorporated in the collection.

The following specialists and institutions rendered us valuable assistance in the naming of our insect specimens :—

1. Imperial Institute of Entomology, London (Miscellaneous insects).
2. The Bureau of Entomology, U. S. A. (Parasites).
3. Dr. F. Barnes, Rothamsted Experimental Station, Harpenden (Cecidomyidæ).
4. Mr. M. S. Mani of Indian Museum, Calcutta (Parasites of Cecidomyiidæ).
5. Mr. L. B. Prout, London (Geometridæ).
6. The Systematic Forest Entomologist, Forest Research Institute, Dehra Dun (Coleoptera).
7. Mr. J. W. Munro, Pretoria, South Africa (Fruit-flies).
8. Mr. W. E. China, British Museum (Natural History), London (Rhynchota).

Of the numerous donors I must make special mention of the Systematic Entomologist, Forest Research Institute, Dehra Dun, who has sent me a large number of named specimens of Coleoptera.

Specimens of the following species were supplied to other workers from our collection :—

Chætodacus cucurbitæ to Professor of Zoology, Government College, Lahore ; *Calandra oryzæ* to Dr. Farooqi, Muslim University, Aligarh ; *Phœdon assamensis* to the Systematic Entomologist, Dehra Dun.

VI. ADVISORY

Identification of insects.—About thirty-four consignments of insect specimens comprising over 60 different species were received from various parts of India and identified as far as possible.

Information about insect pests.—Over fifty enquiries were received and answered from correspondents in India and abroad about the distribution, biology and control of insect pests and parasites, of which the more important are summarized below :—

A comprehensive list of insecticides commonly used in India and information regarding the use of *Tephrosia candida* and other fish poisons were supplied to the Imperial Council of Agricultural Research.

Information about the distribution of codling moth and aphids and preventive measures against fruit-flies in the North-West Frontier Province was supplied to the Director of Agriculture of that province.

Full particulars about the common insecticides which are used for controlling locusts were sent to the Dominion Research Foundation, Calcutta.

Detailed account of *Earias insulana* and its parasite *Habrobracon kitchneri* was supplied to H. I. M.'s Consul for Iran, Bombay.

Information about birds of agricultural importance in India was supplied to the Secretary, Australian Museum, Sydney.

Information about various methods in use of storing grains in India was sent to the Director, Department of Agriculture, Tanganyika, East Africa.

Available data about the importation of insect enemies of *Opuntia* into Australia were supplied to the Chief Scientific Officer, Indian Tea Association, Tocklai, Assam.

Information about insect pests of cultivated olives in India was supplied to the Divisional Forest Officer, Lahore.

A note on the protection of records against ravages of insect pests was sent to the Inspector General of Registration, Patna, Bihar.

Information about the distribution and food-plants of *Pseudococcus lilacinus* was supplied to the Entomologist, Kenya Colony and Protectorate, East Africa.

Bee keeping.—Demand for information on bee-keeping and supply of bee-keeping appliances increased tremendously since our shifting to New Delhi. Several correspondents had to be disappointed due to our inability to meet the demands in full for these appliances.

Issue of certificates.—Several samples of barley and rice meant for despatch to England were fumigated. 171 *Phylloxera* certificates were issued for export of bulbs, orchids, etc.

Coloured plates.—A number of coloured plates of insect pests were supplied to the Cotton Breeder, Jalgaon, Khandesh ; Head Master, Government High School, Gurgaon ; and Entomologist to Government, Punjab, Lyallpur, etc.

VII. MISCELLANEOUS

A brief account of the Progress of Entomology in India during the last twenty-five years was prepared for the publication entitled 'Science Progress in India' by the Indian Science Congress.

A note on the control of termites infesting crops was prepared for broadcasting at the request of the Director, All-India Radio, Delhi.

The Assistant Entomologist broadcast two talks on "Useful and Injurious Insects".

A comprehensive review of the methods in use of fumigation of plant imports in India and in foreign countries was prepared at the request of the Imperial Council of Agricultural Research.

A draft of the section "Entomology—Other insect pests" for the next issue of the *Agriculture and Animal Husbandry in India* was prepared at the request of the Imperial Council of Agricultural Research.

VIII. PUBLICATIONS

The following papers were read at the twenty-fourth annual session of Indian Science Congress Association in January 1937 :—

1. On the *Pyrilla* pest of sugarcane in India.	H. S. Pruthi.
2. *Dasyneura lini*, a new pest of linseed at Pusa.	H. S. Pruthi and H L. Bhatia.
3. The Tur-pod Agromyza	Taskhir Ahmad.
4. On Amaranthus borer and its parasites.	Taskhir Ahmad.
5. The bionomics and life-history of *Coniopteryx pusana*, a predator on the eggs of *Pyrilla*.	E. S. Narayanan.

Papers submitted for publication during the year are given below :—

1. On the *Pyrilla* pest of sugarcane in India.	H. S. Pruthi.
2. Preliminary observations on a new Cecidomyid pest of linseed in India.	H. S. Pruthi and H. L. Bhatia.
3. Further records of the occurrence of Codling moth in India.	H. S. Pruthi.
4. A note on *Stenobracon dessæ* Cam., a new parasite of the root-borer of sugarcane.	E. S. Narayanan.

Reviews of several publications of other scientific workers were published.

IX. PROGRAMME FOR 1937-38

The work during the next year will be more or less on the same lines as in the past year. Pests of fruits, parasites of cotton bollworms and insect vectors of virus diseases will receive special attention.

EXPLANATION OF PLATES

Plate VI

1. Mustard shoot, attacked by aphids. × ⅔
2. Mustard shoot, healthy. × ⅔
3. Castor leaves, damaged by *Euproctis lunata*, young caterpillars. × ⅔
4. Castor leaves, damaged by *Euproctis lunata*, full-grown caterpillars. × ⅔

Plate VII

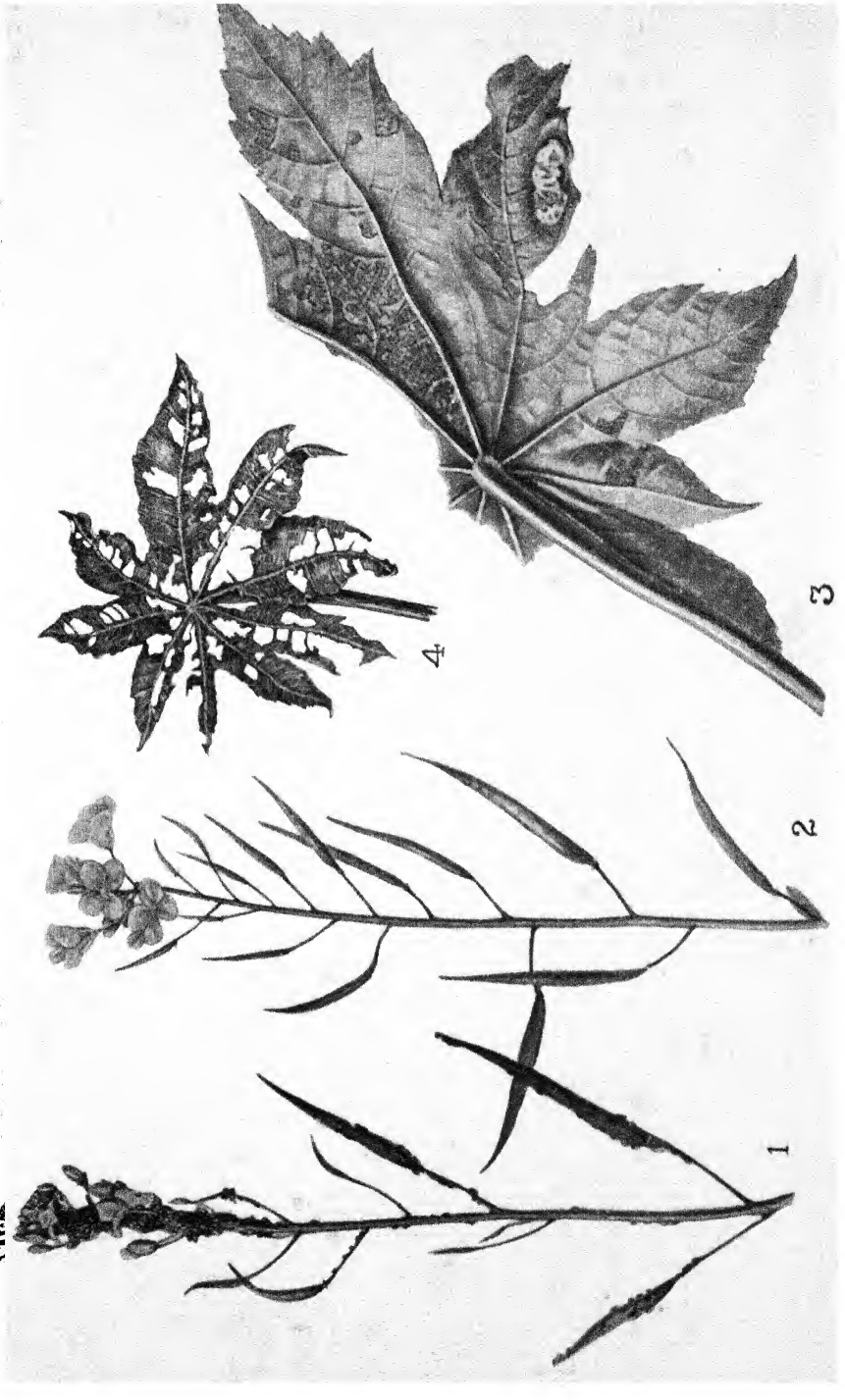
1. *Microbracon gelachidiphagus* Ayyar ×12 on larvæ of spotted bollworm, *Earias insulana*.
2. *Microplitis similis* Lyle ×15 on the cutworm, *Agrotis ypsilon*.

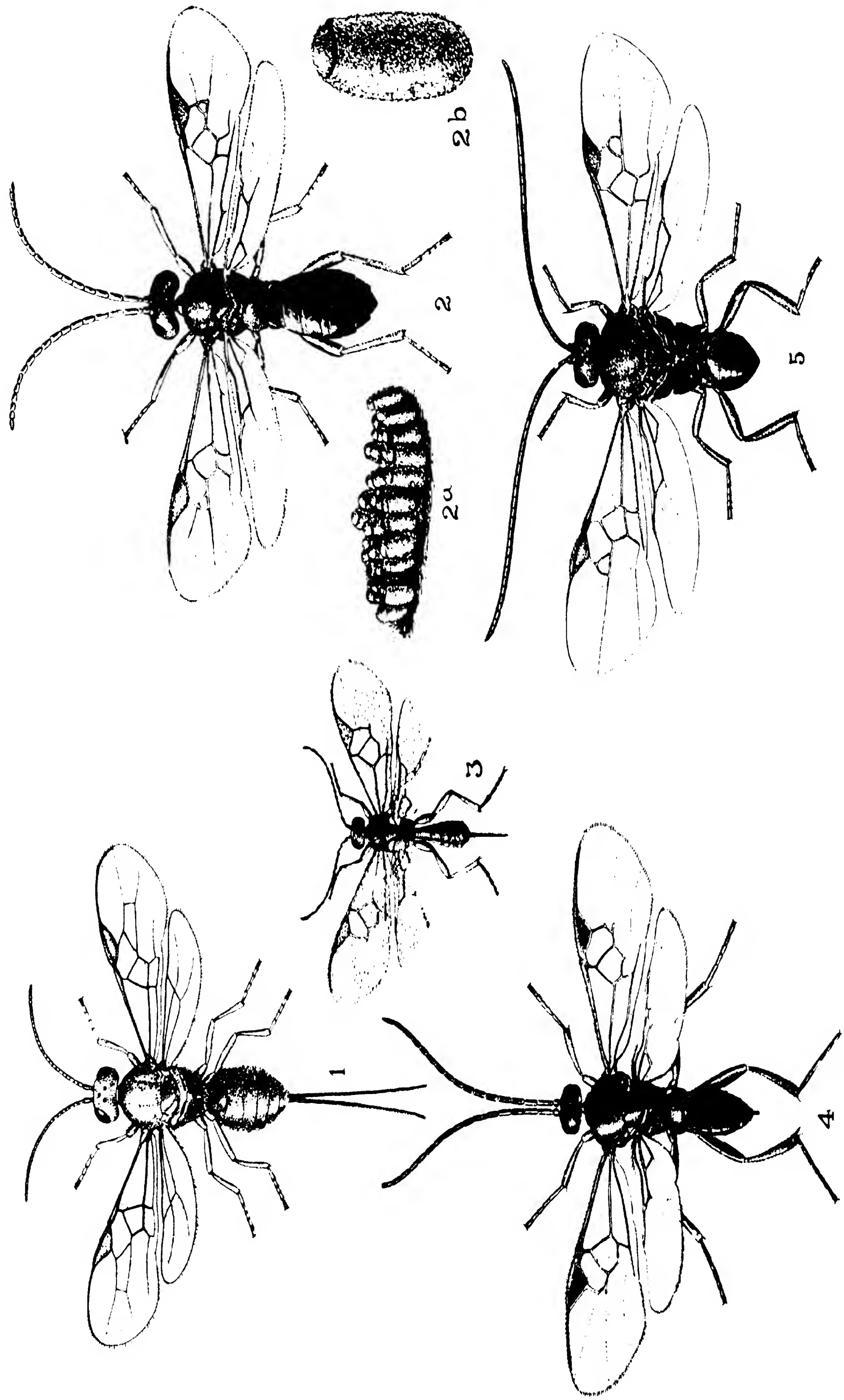
   2*a*. Cluster of cocoons.

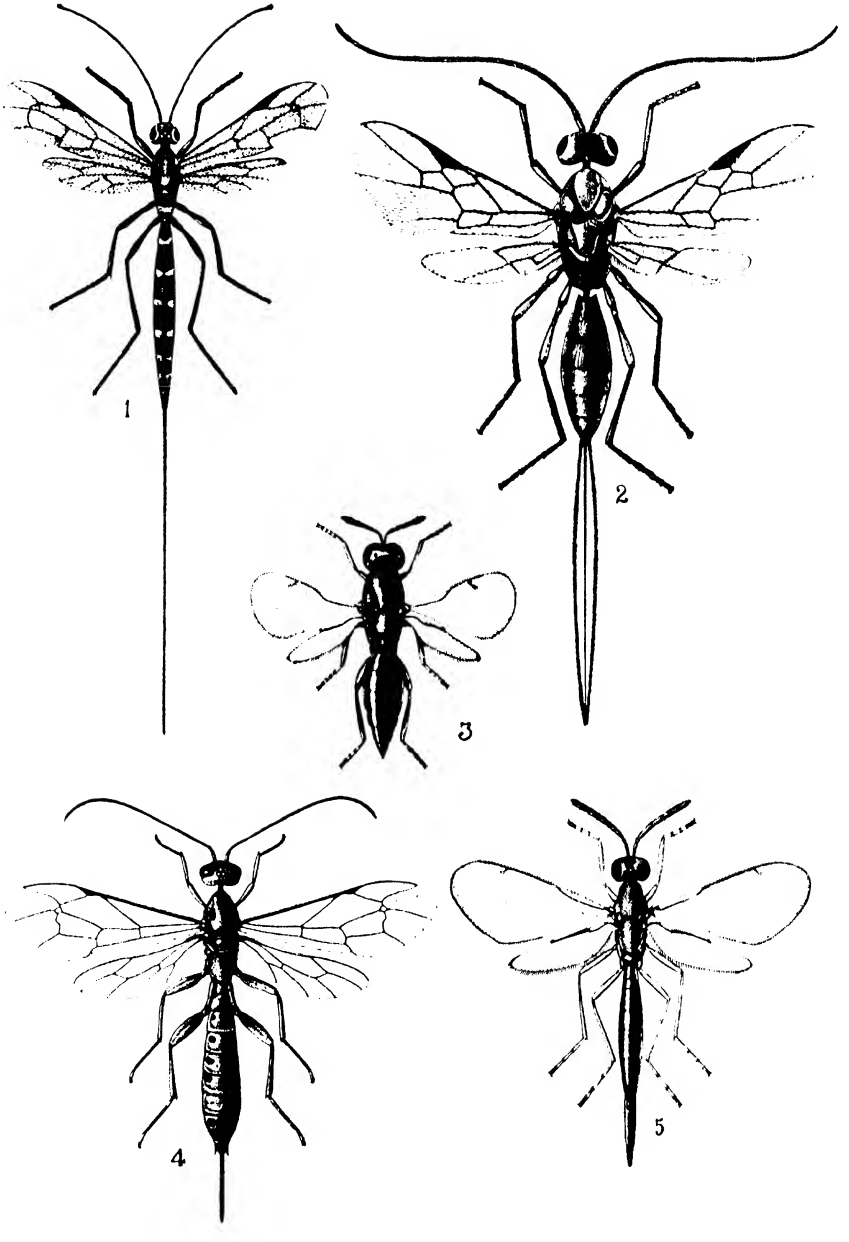
   2*b*. One cocoon enlarged.
3. *Apanteles* sp. ×9 on larvæ of *Sylepta lunalis*, the grape leaf-roller.
4. *Apanteles glomeratus* Lim. ×15 on the caterpillars of *Pieris brassicæ*, the cabbage butterfly.
5. *Microplitus ensirus* Lyle × 12 on the castor semi-looper, *Achœa janata*.

Plate VIII

1. *Rhyssa persuasoria* L. × 1·2 on wood feeding grubs of *Sirex* sp.
2. *Bracon fletcheri* Silv. × 8·4 on maggots of the fruit-fly, *Carpomya vesuviana*.
3. A Chalcid parasite × 12 on larvæ of *Dasyneura lini*.
4. *Xanthopimpla nursei* Cam. × 3·6 on larva of *Chilo simplex*.
5. *Asympiesiella indica* Gir. × 5·6 on larvæ of *Gracillaria soyella*, leaf-roller of *Cajanus Cajan*.


1
2
3
4


2b
2
2a
5
3
1
4


1
2
3
4
5

REPORT OF SECOND ENTOMOLOGIST (DIPTERIST) IN CHARGE

SCHEME FOR RESEARCH ON INSECT PESTS OF SUGARCANE

(P. V. ISAAC)

INTRODUCTION

The Scheme for Research on Insect Pests of Sugarcane was started with the object of conducting observations on the major pests of sugarcane and the investigation of beneficial insects that are inimical to these pests. Work on these lines was to be carried out at the Imperial Agricultural Research Institute at New Delhi and at the Karnal, Pusa and Coimbatore sub-stations by the Second Entomologist (Dipterist) and a special staff. It was also expected that the Provinces would appoint regional field entomologists to study sugarcane pests in their separate areas.

The work at the Imperial Agricultural Research Institute was started after the move of the Institute in 1936 from Pusa to New Delhi, and majority of the special staff was recruited in August and September 1936.

II. SCIENTIFIC

Tours to Karnal, Muzaffarnagar, Mushari, Pusa, Chinsurah, Cuttack, Majhaulia and Padegaon were utilized for the study of the pests prevalent in those places. Immature stages of the different pests collected at those places were brought to the head-quarters and the life-history and habits of the pests and their parasites were under study.

The insects that were reared out from the collections made during the tours were the following :—

Scirpophaga nivella F. This was the chief pest of sugarcane at Karnal from October 1936 to February 1937. It was also collected at Mushari, Muzaffarnagar and Majhaulia in the mature canes.

Scirpophaga monostigma Zell. This was very rare. Only one specimen was collected at Muzaffarnagar.

Diatræa auricilia Ddgn. This was found at Mushari.

Emmalocera depressella Swinh. This was found in numbers at Karnal and Mushari.

The insects that appeared on the young sugarcane crop sown in February-March 1937 were the following :—

Diatræa sticticraspis Hmpsn. It was found to be common at Karnal, Bhopal and locally (Delhi).

Sesamia sp. At Delhi a few of them were noticed.

Chilo zonellus Swinh. At Delhi this pest was found mainly on Sorghum and maize but was noticed on young sugarcane to a small extent.

Emmalocera depressella Swinh. This was the most common borer in young sugarcane plants at Delhi. It was also met with at Karnal.

Pyrilla spp. These were found in very small numbers at Karnal and at Delhi.

A number of parasites were bred out from the material collected at various places and the following is the list :—

Name	Host	Habit	Locality
Melcha ornatipennis Cam.	*Scirpophaga* sp.	On larva	Karnal
Rhaconotus scirpophagæ Wilkn.	,,	,,	,,
Elasmus zehntneri Ferr.	,,	On pupa	,,
Stenobracon deceæ Cam.	*Emmalocera depressella* Swinh.	On larva	,,
	Diatræa sp.	,,	,,
Ditto	*Chilo zonellus* Swinh.	,,	Delhi.
Chlorodryinus pallidus Perks.	*Pyrilla* sp.	On nymphs	Mushari.
Tetrastichus pyrillæ Crawf.	,,	On eggs	Karnal, Chinsurah, Mushari.
Oancyrtus pyrillæ Crawf.	,,	,,	Chinsurah.
Un-identified parasites (Two species of Chalcidoidea).	*Aleurolobus barodensis* Mask.	On nymphs	Karnal, Majhaulia.
Ditto	*Trionymus sacchari* Ckll.	,,	One species at Padegaon, one species at Mushari.

III. SUB-STATIONS

Continuous observations at the sub-stations Karnal, Pusa and Coimbatore were started from the time of the sowing of the 1937 crop of sugarcane.

1. Karnal

Study of the incidence of the different borers of sugarcane is being carried on at this sub-station. With the advent of the sugarcane sowing season in March 1937, special replicated plots with four varieties of sugarcane , *viz.*, Co. 285, Co. 312, Co. 313 and Co. 331, extending over an area of four acres, were laid out for systematic study.

2. Pusa

A few varieties of sugarcane were sown during March to carry on observations on the pests and parasites. An Assistant and a Fieldman were posted there from 1st May 1937 to attend to the work.

The insects that received attention were the egg-parasites of *Scirpophaga* sp. and *Emmalocera depressella* Swinh., and the larval parasite of stem-borers.

3. Coimbatore

Work at the sub-station started from December 1936 when an Assistant and a Fieldman were posted there. Several varieties of sugarcane being available for study at this sub-station, it is proposed to tackle the following aspects :—

1. Varietal susceptibility to the different pests.
2. Influence of morphological characters of the cane on the incidence of the different pests.
3. Influence of planting season on the incidence of the pests.

Among the insects that received attention were the following :—

Icerya pilosa Green. A Coccid recorded for the first time on sugarcane in India.

Novius guerini Crot. A Coccinellid, predator on *Icerya pilosa* Green.

Scirpophaga sp.

Rhaconotus scirpophagæ Wilkn. A parasite on larva of *Scirpophaga* sp.

Stenobracon deesae Cam. A parasite on larva of a stem-borer.

Ichneumonid parasites on larvæ of stem-borers.

IV. MISCELLANEOUS

A meeting of the members of the scientific staff at head-quarters was held once every month to discuss current matters of importance connected with the working of the Section. Papers regarding the observations of individual members during the tours and essays of scientific interest concerning sugarcane pests were read and discussed.

A collated report of the information regarding the pests of sugarcane in India from published reports and statements received from certain Provinces and States and from files available at the Imperial Agricultural Research Institute, was prepared and submitted to the Director for transmission to the Imperial Council of Agricultural Research. A list of the world literature regarding the pests of sugarcane and their parasites and other natural enemies, was under preparation.

GIPD—M598 Dr. IARINew Delhi—23-11-37—500